

**Integrierte Vermeidung und Verminderung  
der Umweltverschmutzung**

**Merkblatt über die  
besten verfügbaren Techniken in der  
Nahrungsmittel-, Getränke- und Milchindustrie**

**Dezember 2005**

mit ausgewählten Kapiteln in deutscher Übersetzung

Das Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit und die 16 Bundesländer haben eine Verwaltungsvereinbarung geschlossen, um gemeinsam eine auszugsweise Übersetzung der BVT-Merkblätter ins Deutsche zu organisieren und zu finanzieren, die im Rahmen des Informationsaustausches nach Artikel 16 Absatz 2 der Richtlinie 96/61/EG über die integrierte Vermeidung und Verminderung der Umweltverschmutzung (IVU-Richtlinie) (Sevilla-Prozess) erarbeitet werden. Die Vereinbarung ist am 10.1.2003 in Kraft getreten. Von den BVT-Merkblättern sollen die für die Genehmigungsbehörden wesentlichen Kapitel übersetzt werden. Auch Österreich unterstützt dieses Übersetzungsprojekt durch finanzielle Beiträge.

Als Nationale Koordinierungsstelle für die BVT-Arbeiten wurde das Umweltbundesamt (UBA) mit der Organisation und fachlichen Begleitung dieser Übersetzungsarbeiten beauftragt.

Die Kapitel des von der Europäischen Kommission veröffentlichten BVT-Merkblattes „Integrierte Vermeidung und Verminderung der Umweltverschmutzung; Referenzdokument über die besten verfügbaren Techniken in der Nahrungsmittel-, Getränke- und Milchindustrie; Dezember 2005“, in denen die Besten Verfügbaren Techniken beschrieben sind (Kap. 4 und 5), sind im Rahmen dieser Verwaltungsvereinbarung in Auftrag des Umweltbundesamtes übersetzt worden.

Die nicht übersetzten Kapitel liegen in diesem Dokument in der englischsprachigen Originalfassung vor. Diese englischsprachigen Teile des Dokumentes enthalten weitere Informationen (u. a. Emissionssituation der Branche, Technikbeschreibungen etc.), die nicht übersetzt worden sind. In Ausnahmefällen gibt es in der deutschen Übersetzung Verweise auf nicht übersetzten Textpassagen. Die deutsche Übersetzung sollte daher immer in Verbindung mit dem englischen Text verwendet werden.

Das Kapitel „Zusammenfassung“ basiert auf der offiziellen Übersetzung der Europäischen Kommission in einer zwischen Deutschland, Luxemburg und Österreich abgestimmten korrigierten Fassung.

Die Übersetzungen der weiteren Kapitel sind ebenfalls sorgfältig erstellt und fachlich durch das Umweltbundesamt und Fachleute der Bundesländer geprüft worden. Diese deutschen Übersetzungen stellen keine rechtsverbindliche Übersetzung des englischen Originaltextes dar. Bei Zweifelsfragen muss deshalb immer auf die von der Kommission veröffentlichte englischsprachige Version zurückgegriffen werden.

Dieses Dokument ist auf der Homepage des Umweltbundesamtes (<http://www.bvt.umweltbundesamt.de/kurzue.htm>) abrufbar.

Durchführung der Übersetzung in die deutsche Sprache:

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This document is one of a series of foreseen documents as below (at the time of writing, not all documents have been drafted):

| <b>Reference Document on Best Available Techniques . . .</b>                         | <b>Code</b>       |
|--|-------------------|
| Large Combustion Plants  | LCP               |
| Mineral Oil and Gas Refineries   | REF               |
| Production of Iron and Steel   | I&S               |
| Ferrous Metals Processing Industry   | FMP               |
| Non Ferrous Metals Industries  | NFM               |
| Smitheries and Foundries Industry  | SF                |
| Surface Treatment of Metals and Plastics   | STM               |
| Cement and Lime Manufacturing Industries   | CL                |
| Glass Manufacturing Industry   | GLS               |
| Ceramic Manufacturing Industry   | CER               |
| Large Volume Organic Chemical Industry   | LVOC              |
| Manufacture of Organic Fine Chemicals  | OFC               |
| Production of Polymers   | POL               |
| Chlor – Alkali Manufacturing Industry  | CAK               |
| Large Volume Inorganic Chemicals - Ammonia, Acids and Fertilisers Industries         | LVIC-AAF          |
| Large Volume Inorganic Chemicals - Solid and Others industry                         | LVIC-S            |
| Production of Speciality Inorganic Chemicals   | SIC               |
| Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector | CWW               |
| Waste Treatments Industries  | WT                |
| Waste Incineration   | WI                |
| Management of Tailings and Waste-Rock in Mining Activities                           | MTWR              |
| Pulp and Paper Industry  | PP                |
| Textiles Industry  | TXT               |
| Tanning of Hides and Skins   | TAN               |
| Slaughterhouses and Animals By-products Industries                                   | SA                |
| <b><i>Food, Drink and Milk Industries</i></b>  | <b><i>FDM</i></b> |
| Intensive Rearing of Poultry and Pigs  | ILF               |
| Surface Treatment Using Organic Solvents   | STS               |
| Industrial Cooling Systems   | CV                |
| Emissions from Storage   | ESB               |
| <b>Reference Document . . .</b>  |                   |
| General Principles of Monitoring   | MON               |
| Economics and Cross-Media Effects  | ECM               |
| Energy Efficiency Techniques   | ENE               |

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## ZUSAMMENFASSUNG

### Einführung

Das Referenzdokument über die besten verfügbaren Techniken (BREF) in der Nahrungsmittel-, Getränke- und Milchindustrie (BVT-Merkblatt) beruht auf einem Informationsaustausch nach Artikel 16 Absatz 2 der Richtlinie 96/61/EG des Rates (IVU-Richtlinie). Diese Zusammenfassung enthält die wesentlichen Ergebnisse, eine Zusammenfassung der wichtigsten BVT-Schlussfolgerungen und die entsprechenden Emissions- bzw. Verbrauchswerte. Das Dokument ist im Zusammenhang mit dem Vorwort zu sehen, das die Zielsetzungen des Dokuments beschreibt, Hinweise zu seiner Verwendung gibt und die verwendeten juristischen Begriffe erläutert. Die Zusammenfassung kann als eigenständiges Dokument betrachtet werden, spiegelt jedoch nicht die gesamte Komplexität der vollständigen Textfassung des Referenzdokuments wider. Bei einer BVT-Entscheidungsfindung ist die Zusammenfassung daher nicht als Ersatz für das gesamte Dokument anzusehen.

### Geltungsbereich

Dieses Dokument beruht auf einem Informationsaustausch zu den in Anhang 1 Punkt 6.4 Buchstaben b) und c) der Richtlinie 96/61/EG des Rates vom 24. September 1996 über die integrierte Vermeidung und Verminderung der Umweltverschmutzung genannten industriellen Tätigkeiten.

#### 6.4. *b) Behandlungs- und Verarbeitungsanlagen zur Herstellung von Nahrungsmittelerzeugnissen aus*

- *tierischen Rohstoffen (mit Ausnahme von Milch) mit einer Produktionskapazität von mehr als 75 t Fertigerzeugnissen pro Tag*
- *pflanzlichen Rohstoffen mit einer Produktionskapazität von mehr als 300 t Fertigerzeugnissen pro Tag (Vierteljahresdurchschnittswert)*

*c) Anlagen zur Behandlung und Verarbeitung von Milch, wenn die eingehende Milchmenge 200 t pro Tag übersteigt (Jahresdurchschnittswert).*

Zum Anwendungsbereich gehören alle industriellen Tätigkeiten zur Herstellung von Nahrungs- und Futtermitteln in europäischen Betrieben mit Kapazitäten, die die oben genannten Schwellenwerte überschreiten.

Das BVT-Dokument (**B**este **V**erfügbare **T**echnik) befasst sich nicht mit kleineren Tätigkeiten wie Catering oder Abläufen in Restaurants oder Tätigkeiten, bei denen keine tierischen oder pflanzlichen Rohstoffe verwendet werden. Auch vorgelagerte Tätigkeiten wie Landwirtschaft, Jagd, Schlachtung und die Herstellung von Erzeugnissen, die nicht als Nahrungsmittel verwendet werden wie z. B. Seife, Kerzen, Kosmetika, Arzneimittel, sowie die Herstellung von Gelatine und Leim aus Häuten, Fellen und Knochen sind nicht behandelt. Industrielles Verpacken ist ebenfalls nicht in dem BVT-Dokument enthalten; das Verpacken von Produkten der Nahrungsmittel-, Getränke- und Milchindustrie in den Herstellungsbetrieben im unmittelbaren Anschluss an die Herstellung wird jedoch behandelt.

### Allgemeine Information (Kapitel 1)

#### Die Nahrungsmittel-, Getränke- und Milchindustrie

Die Nahrungsmittel-, Getränke- und Milchindustrie stellt sowohl Fertigerzeugnisse für den Endverbrauch als auch Zwischenprodukte für die Weiterverarbeitung her. Im Vergleich zu vielen anderen industriellen Tätigkeiten handelt es sich hier um eine Branche mit einer großen Vielfalt an industriellen Tätigkeiten. Die Vielfalt besteht sowohl in Bezug auf die Größe und die Art der Einzelunternehmen, in der breiten Palette von eingesetzten Rohmaterialien, den Erzeugnissen, den Prozessen und deren Kombinationen als auch in Bezug auf die Herstellung von gleichartigen Produkten. Die Produkte sind dabei sowohl auf übernationaler und nationaler als auch auf regionaler Ebene mit speziellen bzw. traditionellen Erzeugnissen anzutreffen. Ein großer Teil der Betriebe sind mittelständische Unternehmen, die allerdings meist mehr als 20 Personen beschäftigen.

In dieser Branche liegen je nach den nationalen Rechtsvorschriften sehr unterschiedliche lokale wirtschaftliche, soziale und umweltbezogene Bedingungen vor. Die Unternehmen dieses Industriezweigs sind in ganz Europa – sowohl in industrialisierten als auch in ländlichen Regionen – angesiedelt. Die Branche exportiert in der EU insgesamt mehr als importiert wird.

Trotz der zunehmenden Vereinheitlichung von Konsum- und Kaufmustern bei immer größerer Vielfalt an Waren weisen die Erzeugnisse der Nahrungsmittel-, Getränke- und Milchindustrie nach wie vor kulturspezifische Elemente auf. Auch wenn die Verbraucher das gleiche Produkt in gleicher Qualität in allen EU-Ländern erwerben wollen, wünschen sie auch eine Auswahl an Erzeugnissen, die ihrer eigenen Tradition oder Kultur entsprechen.

### Die Bedeutung der Lebensmittelsicherheit im Rahmen der Verarbeitung von Nahrungsmitteln, Getränken und Milch

Neben Umwelterwägungen müssen bei der Beschreibung der besten verfügbaren Techniken im Nahrungsmittelsektor auch rechtliche Anforderungen und Verbote berücksichtigt werden. Alle Produktionsanlagen der Branche müssen die geforderten Lebensmittelsicherheitsstandards und entsprechenden Rechtsvorschriften einhalten. Diese Standards wirken sich unter Umständen auf die Umwelt aus; z. B. werden, wenn häufiges Reinigen vorgeschrieben ist, zusätzlich heißes Wasser und Reinigungsmittel verbraucht. Es wurde darauf geachtet, dass keine Aussagen in diesem Dokument den einschlägigen Lebensmittelsicherheits- und Hygienevorschriften widersprechen.

### Die Nahrungsmittel-, Getränke- und Milchindustrie und die Umwelt

Die wichtigsten Umweltfragen im Zusammenhang mit Anlagen der Nahrungsmittel-, Getränke- und Milchindustrie betreffen den Wasserverbrauch und die Wasserverschmutzung, den Energieverbrauch und die Abfallverminderung.

Ein Großteil des Wassers, das nicht als Zusatzstoff verwendet wird, gelangt am Ende ins Abwasser. Unbehandeltes Abwasser aus der Nahrungsmittelbranche weist typischerweise hohe Gehalte an organischen Verunreinigungen (erfasst als CSB- und BSB) auf. Die Konzentrationen können um das 10- bis 100-fache höher sein als im häuslichen Abwasser. Die Schwebstoff-Konzentrationen reichen von vernachlässigbaren Werten bis zu 120.000 mg/l. Unbehandeltes Abwasser aus einigen Branchen wie z. B. der Fleisch-, Fisch- und Milchverarbeitung sowie der Herstellung pflanzlicher Öle weist hohe Konzentrationen an lipophilen Stoffen auf. Es können auch hohe Phosphorwerte auftreten, vor allem, wenn im Prozess große Mengen Phosphorsäure verwendet werden, wie beispielsweise zur Entschleimung von Pflanzenöl oder zur Reinigung.

Die Nahrungsmittel-, Getränke- und Milchindustrie benötigt viel Energie sowohl für die Verarbeitung, als auch für die Frischhaltung der Rohstoffe und Produkte und damit die Gewährleistung der Lebensmittelsicherheit.

Feste Stoffe (Abfälle und Nebenprodukte) entstehen hauptsächlich durch Verschütten, Leckagen, Überlaufen, nicht qualitätsgerecht erzeugte/zurückgerufene Produkte, Schwund, Rückstände, die nicht in den nächsten Verfahrensschritt eingesetzt werden können, und durch Ablagerungen, die beim Erhitzen entstehen. Die Abluft in der Nahrungsmittel-, Getränke- und Milchindustrie enthält hauptsächlich Staub und Geruchsstoffe. Die Geruchsbildung ist ein lokal begrenztes Problem, das entweder mit dem Verfahren selbst oder mit der Lagerung von Rohstoffen, Nebenprodukten oder Abfällen zusammenhängt.

Die entscheidenden Faktoren für eine Verbesserung der Umweltbilanz verändern sich ständig. Beispielsweise hat die maximale Materialausnutzung in der Vergangenheit zu einer Verringerung des Abfallaufkommens geführt. Der unmittelbar auf den Umweltschutz ausgerichtete Ansatz zum Ressourcenschutz stellt die Branche vor große Herausforderungen. Im Hinblick auf die Verringerung des Wasser- und Energieverbrauchs und des Verpackungsanfalls soll gleichzeitig der Hygienestandard aufrecht erhalten bleiben.

### **Angewandte Verfahren und Techniken (Kapitel 2)**

In diesem Dokument können nicht sämtliche in den Branchen verwendeten Verfahren detailliert beschrieben werden. Das Dokument umfasst jedoch ein sehr breites Spektrum an Verfahren in den einzelnen Branchen. Das Kapitel 2 ist in zwei Hauptabschnitte untergliedert. In den Abschnitten 2.1 bis 2.1.9.6.3 werden Arbeitsverfahren auf Anlagenebene beschrieben. Viele davon werden in einer ganzen Reihe von Einzelbranchen eingesetzt. Die gängigsten Verfahren werden anhand von neun Prozesskategorien beschrieben: Wareneingang und Prozessvorbereitung, Größenreduzierung, Mischen und Formen, Trennen, Produktverarbeitung, Wärmebehandlung, Konzentrieren durch Hitze/Einengung, Kühlung, nachfolgende Prozesse und Hilfsprozesse. In diesen neun Prozesskategorien werden jeweils vier bis zu vierzehn Arbeitsverfahren beschrieben.

In den Abschnitten 2.2 bis 2.2.20 wird die Anwendung der Arbeitsverfahren in einigen wichtigen Einzelbranchen beschrieben.

### **Aktuelle Verbrauchs- und Emissionswerte (Kapitel 3)**

Das Kapitel 3 folgt in der Struktur dem Kapitel 2. In diesem Dokument enthält das Kapitel neben Verbrauchs- und Emissionsdaten zusätzliche Informationen zu Stoffen, die keine Endprodukte, aber auch keine Abfälle, sondern z. B. Nebenprodukte sind.

In den Abschnitten 3.1 bis 3.1.4 werden globale Verbrauchs- und Emissionsdaten der Nahrungsmittelbranche insgesamt vorgestellt und ein Überblick über die wichtigsten Verbrauchs- und Emissionsmerkmale gegeben. Die Nahrungsmittel-, Getränke- und Milchindustrie ist ein Großverbraucher an Wasser, das als Zusatzstoff, Reinigungsmittel, Transportmittel und Betriebsstoff für Hilfssysteme eingesetzt wird. Etwa 66 % des gesamten eingesetzten Süßwassers erfordern Trinkwasserqualität. In einigen Bereichen, z. B. Molkereien und Getränkeindustrie, werden bis zu 98 % des verwendeten Wassers in Trinkwasserqualität benötigt. Die Prozesswärme verbraucht etwa 29 % der in der Branche eingesetzten Energie. Etwa 16 % der verbrauchten Gesamtenergie entfallen auf die Prozess- und Materialkühlung.

Die Abschnitte 3.2 bis 3.2.56.3 enthalten Angaben zu Verbrauchs- und Emissionswerten der in Kapitel 2 beschriebenen einzelnen Arbeitsverfahren. Diese Informationen werden unter den Überschriften Wasser, Luftemissionen, feste Stoffe, Energie und Lärm dargestellt.

In den Abschnitten 3.3 bis 3.3.12.3 werden die Verbrauchs- und Emissionsdaten einiger Einzelbranchen der Nahrungsmittel-, Getränke- und Milchindustrie aufgeführt. Durch diese Darstellung kann der Leser auf der Ebene der Arbeitsverfahren Vergleiche zwischen Einzelbranchen und der Gesamtbranche anstellen. Es handelt sich größtenteils um qualitative Informationen. Bei den quantitativen Informationen wird häufig nicht genau dargelegt, welche betrieblichen oder technologischen Verfahren und welche Datenerhebungsmethoden oder -bedingungen angewandt wurden. Die Daten zu Luftemissionen und Abwasseraufkommen liegen für einige Einzelbranchen und sogar für einige Arbeitsverfahren vor. Abfallminimierung wird allgemein als kosteneffizientes Ziel für alle Hersteller angesehen. Es liegen jedoch kaum Richtwerte vor, da der Rohstoffanteil der Endprodukte variabel ist.

Der Detailliertheitsgrad der Angaben zu den Einzelbranchen weist große Unterschiede auf.

### **Techniken, die bei der Festlegung von BVT zu berücksichtigen sind (Kapitel 4)**

Das Kapitel 4 enthält detaillierte Informationen zur Festlegung der BVT für die Nahrungsmittel-, Getränke- und Milchindustrie, auf die sich die technische Arbeitsgruppe (TAG) stützt. Eine Bewertung, ob eine bestimmte Technik als beste verfügbare Technik zu betrachten ist, erfolgt nicht. Das Kapitel folgt dem allgemeinen Aufbau der Kapitel 2 und 3 enthält zunächst Informationen über die Branchen der Nahrungsmittel-, Getränke- und Milchindustrie, bevor abschließend branchenspezifische Angaben zu den einzelnen technischen Prozessen gemacht werden.

Über 370 technische Prozesse werden in der nachfolgenden Gliederung erläutert: Beschreibung des Prozesses, erzielte Umweltvorteile, medienübergreifende Effekte, Betriebsdaten, Anwendbarkeit, Wirtschaftlichkeit, Anlass für die Umsetzung, Beispielanlagen und Referenzliteratur. Die einheitliche Gliederung erleichtert den qualitativen und quantitativen Vergleich zwischen den Techniken.

Kapitel 4 befasst sich weiterhin sowohl mit "prozessintegrierten" als auch mit "nachsorgenden" Techniken. Die meisten Techniken haben mehr als einen Umweltvorteil, einige haben medienübergreifende Auswirkungen. Viele Techniken zielen auf die Verringerung des Wasserverbrauchs und der Wasserverschmutzung sowie des Energieverbrauchs und die bestmögliche Nutzung der Rohmaterialien mit entsprechend verringerter Abfallmenge ab. Für viele Techniken wurden keine Kosten- bzw. Nutzendaten vorgelegt; dass sie angewendet werden, ist jedoch ein Beleg für ihre Wirtschaftlichkeit.

In den Abschnitten 4.1 bis 4.1.9.3 werden zunächst Verfahrensweisen beschrieben, die in allen Anlagen der Nahrungsmittelproduktion angewendet werden können. Dazu gehören betriebliche Verfahren, wie z. B. Management-Instrumente, Ausbildung, Ausstattungs- und Anlagengestaltung, Wartung und Methoden zur

Vermeidung bzw. Verminderung des Wasser- und Energieverbrauchs und der Abfallmenge. Andere Verfahrensweisen sind eher technischer Natur und beziehen sich auf die Produktionssteuerung, Prozessüberwachung und Materialauswahl. Allgemeine Lagerverfahren werden hier nicht behandelt, da sie Thema des BREF zum Thema Lagerung [95, EC, 2005] sind. Spezielle Techniken zur Lagerung von Nahrungsmitteln, durch die der Energieverbrauch bei der Kühlung sowie Abfälle und Gerüche, die durch die Zersetzung von Nahrungsmitteln entstehen, verringert werden können, werden angesprochen.

In den Abschnitten 4.2 bis 4.2.17.4 werden Techniken erläutert, die in einer Reihe von Einzelbranchen angewandt werden. Diese Techniken befassen sich mit der Art und Weise, wie einige in Kapitel 2 beschriebene anlagenspezifische Arbeitsverfahren eingesetzt werden.

Die Reinigung der Geräte und Anlagen ist Gegenstand der Abschnitte 4.3 bis 4.3.11. Die Wahl der Reinigungs- und Desinfektionsmittel muss eine wirksame Kontrolle der Hygieneparameter sicherstellen, zugleich aber auch die Auswirkungen auf die Umwelt entsprechend berücksichtigen.

Endbehandlungstechniken zur Verringerung der Luftemissionen und zur Abwasserbehandlung werden in den Abschnitten 4.4 bis 4.4.3.13.2 bzw. 4.5 – 4.5.7.9 behandelt. Mit der Einführung dieser Abschnitte wird betont, dass bevorzugt prozessintegrierte Techniken zur möglichst weitgehenden Vermeidung und Verminderung von Emissionen in Luft und Abwasser eingesetzt werden sollten. Wenn Endbehandlungstechniken erforderlich sind, dann sollten sie so ausgelegt sein, dass sowohl die Konzentration der Schadstoffe als auch die Schadstoffströme aus einem Arbeitsverfahren oder einem Prozess verringert werden. Die Beschreibungen der Abluftemissionsverminderungstechniken enthalten wenige Informationen zu ihrer Anwendbarkeit oder tatsächlichen Anwendung in den Einzelbranchen der Nahrungsmittel-, Getränke- und Milchindustrie. Dagegen bieten die Beschreibungen der Abwasserbehandlungstechniken mehr Informationen zu ihrer Anwendbarkeit bzw. tatsächlichen Anwendung in Einzelbranchen der Nahrungsmittelindustrie und gehen auf die Behandlung typischer Emissionen von Anlagen der Branche ein, die hohe BSB- und CSB-Werte und einen hohen Gehalt an lipophilen Stoffen, Stickstoff und Phosphor aufweisen.

Die Abschnitte 4.6 bis 4.6.6 behandeln die Vermeidung von Betriebsstörungen in Anlagen der Nahrungsmittelindustrie. Es werden Methoden zur Vermeidung von Betriebsstörungen bzw. Verminderung ihrer Auswirkungen auf die Umwelt beschrieben.

Techniken, die nur in Einzelbranchen in der Nahrungsmittelindustrie anwendbar sind, werden in den Abschnitten 4.7 bis 4.7.9.8.2 beschrieben. Die meisten Techniken in diesen Kapiteln beziehen sich auf spezifische Arbeitsverfahren in einzelnen Branchen der Nahrungsmittelproduktion.

### **Beste verfügbare Techniken (Kapitel 5)**

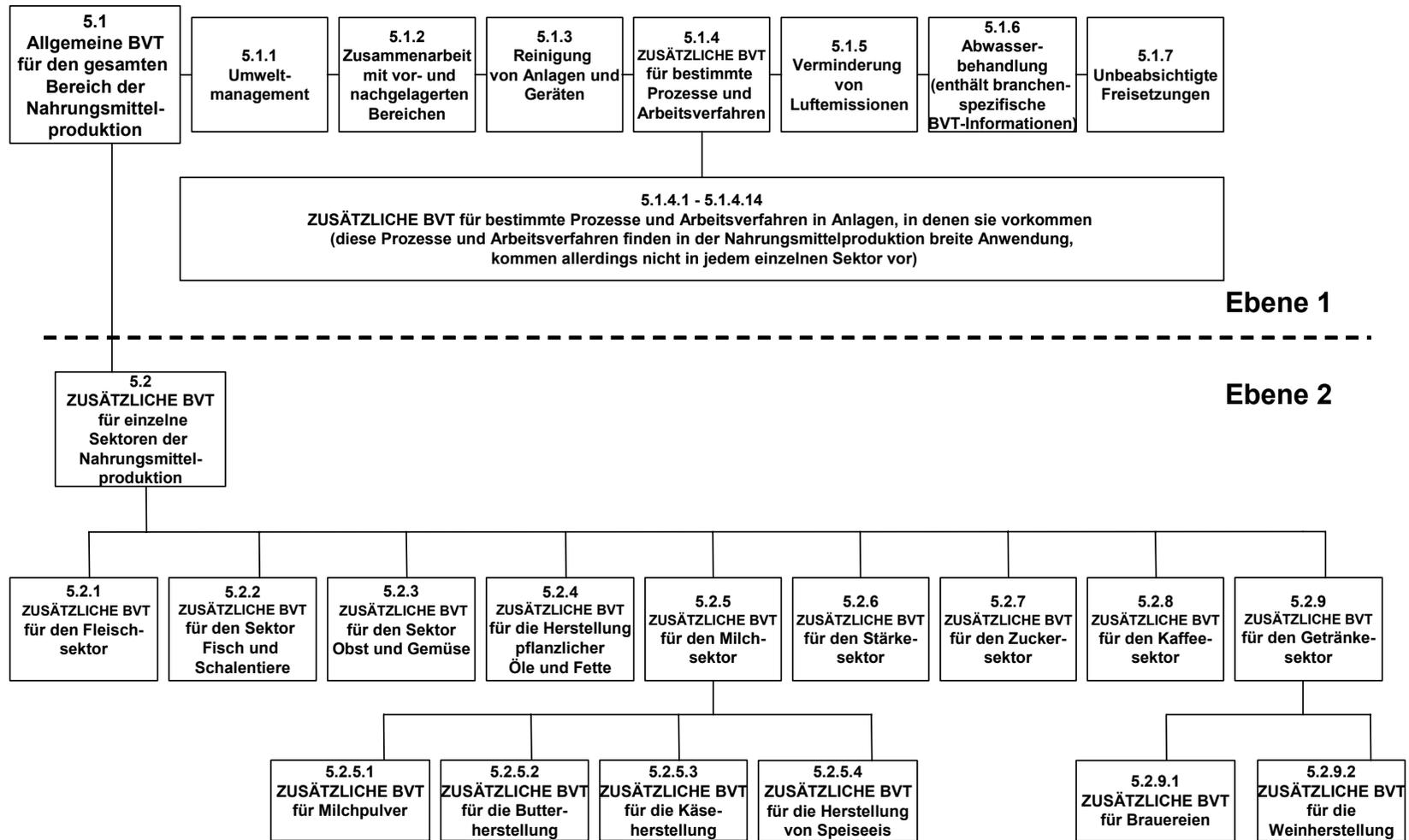
Die Gliederung der in Kapitel 5 dargestellten BVT-Festlegungen kann der folgenden Abbildung entnommen werden. Auf der ersten Gliederungsebene sind die besten verfügbaren Techniken aufgelistet, die für alle Anlagen der Branche gelten. Die zweite Gliederungsebene enthält Abschnitte mit zusätzlichen BVT für einige Einzelbranchen. Das Kapitel 5 folgt der gleichen Gliederungsstruktur wie Kapitel 4. Viele der beschriebenen besten verfügbaren Techniken beziehen sich auf betriebliche Verfahrensweisen und erfordern daher nur geringe Investitionen in neue Ausrüstungen. Ihre Einführung erfordert möglicherweise dennoch Investitionen wie z. B. in die Ausbildung, Wartung oder ständige Überwachung und Kontrolle der erreichten Ergebnisse.

Die ausgewählten Techniken stellen für den Bereich der Nahrungsmittel-, Getränke- und Milchindustrie die allgemein besten verfügbaren Techniken nach Meinung der technischen Arbeitsgruppe (TAG) dar. Die TAG stützt sich bei dieser Auswahl auf die in Kapitel 4 enthaltenen Informationen. Außerdem wurden sowohl die in Artikel 2 Absatz 11 der RL 96/61/EG gegebene Definition einer "besten verfügbaren Technik" als auch die Anmerkungen aus Anhang IV der Richtlinie berücksichtigt. In Kapitel 5 werden keine Verbrauchs- und Emissionsgrenzwerte festgelegt. Vielmehr erhalten die Industrie, die Mitgliedstaaten und die Öffentlichkeit Informationen über Verbrauchs- und Emissionswerte, die bei der Verwendung der erörterten Techniken erreicht werden können.

Die folgenden Abschnitte enthalten eine Zusammenfassung der wesentlichen BVT-Schlussfolgerungen zu den Prozessen mit maßgeblicher Umweltrelevanz. Mit sehr wenigen BVT-Festlegungen ist lediglich nur ein Umweltvorteil verbunden. Daher werden sie nicht nach Umweltfragen gesondert gegliedert. Die BVT enthalten insgesamt verschiedenste Aspekte zum Schutz der Umwelt. Diese Umweltschutzmaßnahmen reichen von der

allgemeinen Betriebsführung und den Betriebsabläufen, die auf alle Anlagen der Branche anwendbar sind, bis zum Einsatz sehr spezieller Verfahren in einzelnen Bereichen der Nahrungsmittelproduktion.

Im Rahmen der Erörterung innerhalb der TAG wurden zahlreiche Themen angesprochen und diskutiert. Daher sollte die Zusammenfassung nicht ohne das Kapitel über die “besten verfügbaren Techniken” gelesen werden, welches wiederum nicht losgelöst vom Rest des BVT-Merkblattes gesehen werden kann.



Darstellung der BVT-Schlussfolgerungen für Anlagen der Nahrungsmittel-, Getränke- und Milchindustrie

## Allgemeine BVT für die gesamte Nahrungsmittel-, Getränke- und Milchindustrie

Obwohl die Nahrungsmittelindustrie eine große Vielfalt aufweist, geht es in den einzelnen Branchen häufig um gemeinsame Fragestellungen, wie z. B. um ähnlich gelagerte Umweltprobleme. Hier sind dieselben BVT für die Vermeidung und Verminderung von Verbräuchen und Emissionen anwendbar, wie beispielsweise die trockene Reinigung zur Verringerung des Wasserverbrauchs. Außerdem dienen einige BVT der gleichzeitigen Vermeidung mehrerer Umweltprobleme. Die Wartung beispielsweise dient bei Kühlanlagen zur Verhinderung des Austretens von Ammoniak oder bei Fischenthäutungsmaschinen zur Verringerung der Abfälle, die durch das unerwünschte Entfernen von Fischfleisch beim Enthäuten anfallen.

### Allgemeine Betriebsführung

Die BVT-Angaben für die allgemeine Betriebsführung tragen zur allgemeinen Senkung der Verbrauchs- und Emissionswerte bei, indem Arbeitsabläufe vorgegeben werden, welche die Anwendung einer guten Verfahrenspraxis fördern und das Problembewusstsein stärken. Die beschriebenen BVT beschäftigen sich insbesondere mit folgenden Themen: Einführung eines Umweltmanagementsystems, Aus- und Weiterbildung, Wartungskonzept, konsequente Anwendung einer Methodik zur Minimierung des Wasser- und Energieverbrauchs und Vermeidung von Abfällen und Einführung eines Systems zur Überwachung und Kontrolle der Verbrauchs- und Emissionswerte sowohl im einzelnen Produktionsprozess als auch in der Anlage insgesamt.

### Allgemeine Verfahrensabläufe

Spezielle BVT befassen sich unmittelbarer mit bestimmten maßgeblichen Umweltbereichen, wie z. B. dem trockenen Transport von festen Rohstoffen, Produkten, Koprodukten, Nebenprodukten und Abfällen. Dadurch wird der Wasserverbrauch reduziert. In der Folge fällt dadurch weniger und geringer belastetes Abwasser an. Das Potenzial zur Rückgewinnung und Wiederverwertung von Stoffen, die im Prozess anfallen, wird dadurch erhöht, dass diese in vielen Fällen zur Verwertung als Tierfutter verkauft werden können. Durch diese Maßnahmen wird die Abfallproduktion verringert.

Ein weiteres Beispiel für Maßnahmen, die in der gesamten Nahrungsmittel-, Getränke- und Milchindustrie anwendbar sind, ist die Trennung der Stoff- und Abwasserströme zur Optimierung der Verwendung, Wiederverwendung, Rückgewinnung, Wiederverwertung und Entsorgung sowie zur Minimierung der Abwasserbelastung. Es gibt in der Lebensmittelbranche zahlreiche Beispiele dafür, dass Rohstoffe, teilverarbeitete Lebensmittel und Endprodukte, die entweder ursprünglich für den menschlichen Verbrauch vorgesehen waren oder von denen der Teil, der für den menschlichen Gebrauch geeignet ist, entfernt wurde, als Tierfutter verwendet werden können. Das hat sowohl ökologische als auch wirtschaftliche Vorteile.

### Allgemeine Anwendung von Technologien

Einige verstärkt technisch ausgerichtete BVT betreffen den Einsatz und die Nutzung einer Prozesssteuerung, wie z. B. durch die Verwendung von analytischen Mess- und Kontrollverfahren zur Verringerung von festen Abfällen und Abwasser sowie zur Verringerung der Abwassermenge bei der Verarbeitung und der Reinigung. Ein Beispiel dafür ist die Trübungsmessung zur Überwachung der Qualität des Prozesswassers und zur Optimierung sowohl der Rückgewinnung von Stoffen bzw. Produkten aus dem Wasser als auch der Wiederverwendung von Reinigungswasser.

### Zusammenarbeit mit vor- und nachgelagerten Bereichen

Die Tätigkeiten der mit der Lieferung von Roh-, Hilfs- und Zusatzstoffen an Anlagen zur Nahrungsmittelverarbeitung befassten Personen (u. a. Landwirte und Transportunternehmer) wirken sich auf die Umweltbedingungen in den Anlagen der Nahrungsmittel-, Getränke- und Milchindustrie aus. Gleichermaßen kann die Anlage der Nahrungsmittelindustrie die Umweltbedingungen nachgeschalteter Anlagen, die sie beliefert, beeinflussen, zum Beispiel andere Anlagen der Nahrungsmittelindustrie. Die BVT bestehen darin, die Zusammenarbeit mit vor- und nachgeschalteten Partnern anzustreben, um ein durchgehendes System der Umweltverantwortung zu schaffen, die Umweltverschmutzung zu minimieren und die Umwelt als Ganzes zu schützen. Als Beispiel wird die Anlieferung der benötigten frischen Materialien zur richtigen Zeit beschrieben,

## Zusammenfassung

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wodurch der Energiebedarf für ihre Lagerung und Abfälle und Gerüche, die bei ihrem Zerfall entstehen, minimiert werden.

### Reinigung von Geräten und Anlagen

Die Anwendung der besten verfügbaren Techniken zur Reinigung führt zu einer Minimierung des Wasserverbrauchs und der Wasserverschmutzung, des Abfalls, des Abfallanfalls, des Energieverbrauchs und der Menge und Schädlichkeit der benutzten Reinigungsmittel.

Die BVT für die Reinigung in den Anlagen und Einrichtungen sorgen dafür, dass Nahrungsmittel weniger mit Wasser in Kontakt kommen, indem beispielsweise überall dort, wo dies möglich ist, die trockene Reinigung zuerst angewandt wird. Zu den Umweltvorteilen gehören ein geringerer Wasserverbrauch und die Entstehung von weniger Abwasser, ein verringerter Materialeintrag ins Abwasser und folglich geringere CSB- und BSB-Werte. Die Anwendung der verschiedenen Trockenreinigungstechniken eröffnet mehr Möglichkeiten zur Rückgewinnung und Wiederverwertung von im Prozess erzeugten Stoffen. Sie verringern auch den Energiebedarf zur Erwärmung von Wasser für Reinigungszwecke und den Einsatz von Reinigungsmitteln.

Weitere BVT für das Reinigen umfassen die CIP-Reinigung in geschlossenen Anlagen, die Minimierung der Verwendung von EDTA und die Vermeidung des Einsatzes halogenierter oxidierender Biozide.

### Zusätzliche BVT für einige Prozesse und Arbeitsverfahren in mehreren Bereichen der Nahrungsmittelproduktion

Die TAG einigte sich auf beste verfügbare Techniken für einige individuelle Arbeitsverfahren, die nur in einzelnen Bereichen der Nahrungsmittelproduktion (in der Regel nicht in allen) angewendet werden. Es werden BVT für die Warenannahme/-abfertigung, die Zentrifugation/Separation, das Räuchern, das Garen, das Braten, die Konservierung in Dosen, Flaschen und Gläsern, die Verdampfung, das Gefrieren und das Kühlen, das Verpacken, die Energieerzeugung und -verwendung, die Wasserverwendung, Druckluftsysteme und Dampfsysteme aufgeführt. Durch die Anwendung vieler dieser BVT wird ein reduzierter Energieverbrauch erreicht, wie beispielsweise durch den mehrstufigen Verdampfer zur Einengung von Flüssigkeiten mit je nach der in der Anlage verfügbaren Wärme und Energie aus der optimierten Brüdenverdichtung. In vielen Fällen wird eine Verringerung des Energieverbrauchs durch eine Optimierung der Betriebsbedingungen erreicht. Einige BVT sorgen für eine Verringerung der Luftemissionen. So legt beispielsweise die BVT für das Räuchern fest, dass ein TOC-Wert in der Abluft von  $<50 \text{ mg/Nm}^3$  zu erreichen ist.

### Minimierung der Luftemissionen und Abwasserbehandlung

Es sollten innerbetriebliche BVT angewandt werden, die durch die Auswahl und den Einsatz von Stoffen und Techniken eine Minimierung der Emissionen in Luft und Wasser bewirken. Bei Bedarf können darüber hinaus zusätzlich Verfahren zur Verminderung der Luftemissionen und zur Abwasserbehandlung eingesetzt werden. Als BVT sind hier beispielsweise zu nennen: Optimierung des Einsatzes trockener Reinigungsverfahren und damit Verringerung der Abwassermenge sowie des Eintrags von Lebensmittelresten. Dadurch muss weniger Abwasser behandelt werden.

Es gilt als BVT, eine Kontrollstrategie für Luftemissionen einzusetzen und entsprechende Verminderungsmaßnahmen anzuwenden, falls die Emissionswerte von  $5\text{-}20 \text{ mg/Nm}^3$  für trockenen Staub,  $35\text{-}60 \text{ mg/Nm}^3$  für nassen/klebrigen Staub und  $<50 \text{ mg/Nm}^3$  TOC mit Hilfe von prozessintegrierter BVT zur Minimierung von Luftemissionen durch Auswahl und Einsatz von Stoffen und Anwendung von Verfahren überschritten werden.

In der Frage, ob es insgesamt besser ist, Abwasser aus Anlagen der Nahrungsmittelindustrie (abgesehen von speziellen Vorreinigungsverfahren) betriebsintern oder betriebsextern zu behandeln, wurde kein einvernehmliches Ergebnis gefunden.

Falls im BVT-Kapitel nicht anders festgelegt, stehen die in der folgenden Tabelle angegebenen Emissionswerte für Abwasser als Hinweise auf die Werte, die bei Einsatz der allgemein als BVT angesehenen Techniken erreicht werden können. Sie repräsentieren nicht unbedingt die zurzeit in der Branche erzielten Werte, sondern beruhen vielmehr auf dem Fachurteil der TAG.

| Parameter   | Konzentration<br>(mg/l) |
|---|-------------------------|
| BSB <sub>5</sub>  | <25                     |
| CSB   | <125                    |
| TSS   | <50                     |
| pH  | 6 – 9                   |
| Lipophile Stoffe  | <10                     |
| Stickstoff, gesamt  | <10                     |
| Phosphor, gesamt  | 0,4 – 5                 |
| Es können niedrigere BSB <sub>5</sub> - und CSB-Werte erzielt werden. Es ist in Anbetracht lokaler Bedingungen nicht immer möglich oder kostenwirksam, die angegebenen Gesamtwerte für Stickstoff und Phosphor einzuhalten. |                         |

### Typische Qualität der Abwässer aus Anlagen der Nahrungsmittelindustrie nach Behandlung

Ein Mitgliedstaat (Deutschland) hat eine abweichende Meinung geäußert. Der Mitgliedstaat ist mit der Fußnote in der obigen Tabelle nicht einverstanden, weil er der Ansicht ist, dass Abweichungen von den BVT beispielsweise aufgrund lokaler Bedingungen ausschließlich erlaubt sind, um die Genehmigungsanforderungen zu verschärfen.

### Unbeabsichtigte Freisetzung

Verschiedene BVT werden aufgeführt, die sich auf die Ermittlung potenzieller Unfälle, Risikobewertung, Überwachung der Umsetzung, Entwicklung und Erprobung von Notfallplänen und Lehren aus vergangenen Betriebsstörungen und Beinahe-Betriebsstörungen beziehen.

### Zusätzliche BVT für einzelne Produktionsbereiche der Nahrungsmittelherstellung

Für einzelne Produktionsbereiche der Nahrungsmittelproduktion wurden zusätzliche BVT festgelegt. Die allgemeinen BVT in den Abschnitten 5.1 bis 5.1.7 gelten für diese einzelnen Produktionsbereiche sowie für die anderen Hersteller, für die keine zusätzlichen BVT festgelegt wurden. Durch die Anwendung von allgemeinen BVT, wie beispielsweise die Trennung der Stoff- und Abwasserströme und die Optimierung der Anwendung von trockener Reinigung, kann die Umweltbelastung eines Prozesses insgesamt deutlich verringert werden.

Die zusätzlichen BVT für die Fleisch- und Geflügelverarbeitung beziehen sich auf spezifische Arbeitsverfahren, die in einigen Teilen dieser Branche angewandt werden. Durch die Anwendung dieser BVT wird der Wasser-, Energie- und Verpackungsverbrauch verringert.

Die wichtigsten Umweltvorteile der zusätzlichen BVT für den Sektor Fisch und Schalentiere sind geringere Abfallmengen und weniger Wasserverbrauch. Einige BVT gelten für das Auftauen, Schuppen, Häuten, Ausnehmen und Filetieren von Fisch. Beispielsweise wurden BVT für das Auftauen von Makrelen mit einem Wasserverbrauch von <math><2\text{ m}^3/\text{t}</math> Rohfisch festgelegt sowie für das Auftauen von Weißfisch mit einem Wasserverbrauch von 1,8 – 2,2  $\text{m}^3/\text{t}$  Rohfisch und für das Auftauen von Krabben und Garnelen nach einem von zwei Verfahren unter Verwendung von gefiltertem Schälwasser.

In den BVT für Obst und Gemüse geht es um Lagerung, trockene Trennung von verworfenen Rohstoffen, Auffangen der Erde, Schälen, Blanchieren und Optimierung der Wiederverwendung von Wasser. Die Anwendung der BVT führt zu einer Maximierung der Ausbeute. Nicht für das Hauptprodukt verwertbare Stoffe können für andere Zwecke, häufig als Tierfutter, verwendet werden, was zu einer Verringerung der Abfallmenge beiträgt. Zu den Umweltvorteilen einer Anwendung der BVT für die Lagerung, das Schälen und das Blanchieren gehört beispielsweise ein verminderter Energieverbrauch.

Die Umweltvorteile einer Anwendung der zusätzlichen BVT für die Herstellung pflanzlicher Öle und Fette bestehen im Wesentlichen in der Senkung des Energieverbrauchs und der Rückgewinnung des bei der Extraktion eingesetzten Hexans. Ein BVT-Emissionswert wurde festgelegt. Es gilt als BVT in der Branche Zyklone zu verwenden, um die Feuchtstaub-Emissionen aus der Extraktion von Pflanzenöl zu senken und einen Emissionswert für Feuchtstaub von <math><50\text{ mg}/\text{Nm}^3</math> zu erreichen.

Es gibt zusätzliche BVT für Molkereien und spezifische BVT für die Herstellung von Marktmilch, Milchpulver, Butter, Käse und Speiseeis. Die BVT beziehen sich auf spezifische Teile der Herstellungsprozesse und auf die Reinigung. Sie betreffen den Wasser- und Energieverbrauch und die Vermeidung von Abfällen. Es gibt sowohl verfahrenstechnische als auch technologische BVT. Auf der Grundlage der in der Branche erzielten und von der TAG berichteten Werte wurden Verbrauchs- und Emissionswerte festgelegt, die bei Einsatz innerbetrieblicher Maßnahmen erreicht werden können. Diese Werte sind in der folgenden Tabelle aufgeführt. Sie spiegeln vielfältige Betriebsbedingungen wider. Der Energieverbrauch kann je nach Produktionsvolumen variieren. In warmem Klima wird mehr Energie für die Kühlung benötigt, in kaltem weniger. Der Wasserverbrauch und die Abwassermengen können beispielsweise aufgrund verschiedener Produktportfolios, Chargengrößen und Reinigungsverfahren unterschiedlich sein. Im Vergleich zum Wasserverbrauch können die Abwassermengen niedriger sein, denn viele Molkereien messen die Menge des eingespeisten Kühlwassers, aber nicht den Abfluss. In warmem Klima kann Wasser durch Verdunstung zusätzlich verloren gehen.

|   | <b>Energie-<br/>verbrauch</b> | <b>Wasser-<br/>verbrauch</b> | <b>Abwasser</b> |
|---|-------------------------------|------------------------------|-----------------|
| Herstellung von Marktmilch aus 1 Liter angelieferter Milch  | 0,07 – 0,2 kWh/l              | 0,6 – 1,8 l/l                | 0,8 – 1,7 l/l   |
| Herstellung von Milchpulver aus 1 Liter angelieferter Milch | 0,3 – 0,4 kWh/l               | 0,8 – 1,7 l/l                | 0,8 – 1,5 l/l   |
| Herstellung von 1 kg Speiseeis                              | 0,6 – 2,8 kWh/kg              | 4,0 – 5,0 l/kg               | 2,7 – 4,0 l/kg  |

### Verbrauchs- und Emissionswerte für einige Herstellungsverfahren bei der Milchverarbeitung

Bei der Anwendung zusätzlicher BVT für die Stärkeherstellung geht es hauptsächlich um eine Senkung von Wasserverbrauch und Abwassermenge, vor allem durch die Wiederverwendung von Wasser.

Mit der Wiederverwendung von Wasser beschäftigen sich auch die BVT für die Zuckerherstellung. Eine Minimierung des Energieverbrauchs wird in diesem Bereich dadurch erreicht, dass vermieden wird, Zuckerrübenschnitzel zu trocknen, wenn eine Absatzmöglichkeit für Zuckerrübenschnitzel vorhanden ist, z. B. als Tierfutter. Ansonsten sollten Zuckerrübenschnitzel in Dampf- oder Hochtemperaturtrocknern getrocknet werden und Maßnahmen zur Verminderung der Emissionen in die Luft angewandt werden.

Die größten Umweltbelastungen bei der Kaffeeröstung sind der Energieverbrauch und Emissionen in der Abluft (u. a. Geruch). Diese Belastungen können durch die Anwendung zusätzlicher BVT für die Kaffeeröstung verringert werden. Falls die Luftemissionen die Emissionswerte von 5-20 mg/Nm<sup>3</sup> für trockenen Staub und <50 mg/Nm<sup>3</sup> TOC bei leicht geröstetem Kaffee (dieser Wert ist schwieriger zu erreichen, wenn dunkler geröstet wird) überschreiten, sehen die BVT für die Kaffeeröstung prozessintegrierte Maßnahmen zur Minimierung von Luftemissionen durch Auswahl und Einsatz von Stoffen und Anwendung von Verfahren vor, um diese Werte zu erreichen. Emissionswerte für NO<sub>x</sub> wurden zu spät vorgelegt und konnten von der TAG nicht mehr eingehend geprüft werden. Sie werden in den Schlussbemerkungen genannt.

Die zusätzlichen BVT für die Getränkeherstellung betreffen folgende Punkte: Vermeidung der Erzeugung von CO<sub>2</sub> direkt aus fossilen Brennstoffen, Heferückgewinnung, Entsorgung verbrauchter Filtermedien und die Auswahl und optimale Nutzung von Flaschenreinigungsmaschinen. Durch die Anwendung der zusätzlichen BVT für Brauereien werden sowohl der Wasser- als auch der Energieverbrauch gesenkt. Als BVT im Brauereiwesen gelten Wasserverbrauchswerte von 0,35 – 1 m<sup>3</sup>/hl produzierten Biers. Die zusätzlichen BVT für die Weinherstellung sehen die Wiederverwendung der zur Reinigung verwendeten Alkalilösung nach der Kaltstabilisierung vor und umfassen Methoden zur abschließenden Entsorgung von Nebenprodukten, um Störungen in der Abwasserbehandlungsanlage zu verhindern.

### Techniken in der Entwicklungsphase (Kapitel 6)

In Kapitel 6 wird eine Technik vorgestellt, die noch nicht kommerziell genutzt wird und sich noch im Forschungs- bzw. Entwicklungsstadium befindet. Sie betrifft den "Einsatz von UV/Ozon zur Geruchsminderung". Sie wurde in das vorliegende Dokument aufgenommen, um den Sachstand für eine künftige Überarbeitung des Dokuments einzubringen.

## Schlussbemerkungen (Kapitel 7)

### Zeitraumen der Arbeit

Die Arbeit an diesem Dokument wurde mit der Plenarsitzung der technischen Arbeitsgruppe (TAG) im Januar 2001 aufgenommen. Die letzte Plenarsitzung der technischen Arbeitsgruppe fand im Februar 2005 statt.

### Grad des Konsenses, Motivation für die Umsetzung und auf der Schlusssitzung der TAG aufgeworfene Fragen

Die aus der Arbeit gezogenen Schlussfolgerungen wurden auf der abschließenden Plenarsitzung mit weitgehender Übereinstimmung verabschiedet. Es wurden aber auch einige Fragen aufgeworfen. Es wird empfohlen, diese Fragen bei der Überarbeitung des vorliegenden Dokuments aufzugreifen und weiter zu vertiefen.

### Mitgeteilte Informationen

Für die Erstellung dieses Dokuments wurden zahlreiche Berichte von Behörden aus den Mitgliedstaaten und aus der Industrie als Informationsquellen verwendet. Außerdem sind Informationen aus den Beispielanlagen und von Betriebsbesichtigungen eingeflossen. Die Beteiligung einzelner Mitgliedstaaten an der Arbeit spiegelte in einem gewissen Umfang die regionale Verteilung der Branchen wider. Die Vereinigung der Ernährungsindustrien in der EU (CIAA) und die in ihr zusammengeschlossenen Organisationen lieferten die meisten Beiträge aus der Industrie.

Durch den Informationsaustausch und die Erarbeitung dieses Dokuments haben die Vermeidung und Verminderung der Umweltverschmutzung in den betroffenen Branchen wichtige neue Impulse erhalten. Für einzelne Branchen war dies eine erste Gelegenheit, Techniken kennen zu lernen, die sich europaweit in anderen Branchen bereits bewährt haben.

### Ungenau und lückenhafte Informationen

Die Informationen über einzelne Branchen der Nahrungsmittel-, Getränke- und Milchindustrie sind sehr unterschiedlich detailliert und decken zudem nicht alle wesentlichen Umweltfragen dieses Dokuments ab. Die gelieferten aktuellen Verbrauchs- und Emissionswerte wurden nicht in Bezug zu den angewandten Verfahren, den Betriebsbedingungen, der Anlagenleistung, der Art der Probenahmen und analytischen Verfahren und der statistischen Aufbereitung gesetzt. In diesem Dokument werden Techniken beschrieben, durch die der Energieverbrauch gesenkt werden kann. Konkrete Messergebnisse, die Aufschluss über die durch die Anwendung der beschriebenen Techniken erzielten Energieeinsparungen bzw. die mit den entsprechenden Investitionen und den damit verbundenen Kosteneinsparungen erreichten Einsparungen geben, wurden jedoch nicht geliefert. Es werden keine Benchmarks für die Abfallminimierung mitgeteilt; beispielsweise fehlen detaillierte Informationen darüber, welcher Anteil spezifizierter Rohstoffe letztendlich in die Produkte oder Nebenprodukte einfließt.

### Empfehlungen für zukünftige Arbeiten

Die Lücken in den erhaltenen Informationen verdeutlichen, in welchen Bereichen künftige Arbeiten dazu beitragen könnten, bei der Überarbeitung dieses Dokuments beste verfügbare Techniken herauszukristallisieren und Betreiber von Anlagen und Genehmigungsbehörden beim Schutz der Umwelt umfassend zu unterstützen. Es wird empfohlen, Informationen zu folgenden Themen bereitzustellen:

- Beschreibung der angewandten Verfahren, Betriebsbedingungen, Probenahme- und Analyseverfahren sowie die statistische Aufbereitung von Verbrauchs- und Emissionswerten
- die gesamte Palette möglicher Anwendungen der im vorliegenden Dokument beschriebenen Techniken
- weitere Möglichkeiten der Steigerung der Ausbeute an Nebenprodukten zur Minimierung der Abfallmengen
- Investitions- und Betriebskosten der Techniken und die damit verbundenen direkten und indirekten Kosteneinsparungen, beispielsweise durch gesenkte Energie- und Abfallbeseitigungskosten oder weniger Verluste durch unkontrolliertes Aus- oder Überlaufen
- Festlegung von BVT im Zusammenhang mit Hochdruck-, Mitteldruck- und Niederdruck-Reinigung
- bereits gebräuchliche Ersatzstoffe für EDTA in Reinigungsmitteln
- Anwendung und Anwendbarkeit von Verfahren zur Reinhaltung der Luft in der Nahrungsmittel-, Getränke- und Milchindustrie

- Anwendung der nicht-thermischen Plasmabehandlung von Geruchsstoffen in der Nahrungsmittel-, Getränke- und Milchindustrie
- Techniken zur Vermeidung der Einleitung von abdestilliertem Alkohol bei der Herstellung alkoholfreien Biers in die Abwasseraufbereitungsanlage
- Einfluss saisonaler Aktivitäten auf die technische und wirtschaftliche Tragfähigkeit der Techniken
- Techniken zur Extraktion von Olivenöl, insbesondere die „Zweiphasenextraktion“
- Einsatz der enzymatischen Umesterung und der enzymatischen Entschleimung von Pflanzenöl
- vergleichende Informationen zur Entschleimung von Pflanzenölen mit Enzymen, Phosphorsäure und Zitronensäure
- Techniken zur Minimierung von NO<sub>x</sub>-Emissionen aus Kaffee-Röstanlagen und
- Auswahl und Einsatz von Räuchermitteln.

### Themenvorschläge für zukünftige Projekte im Bereich Forschung und Entwicklung

Folgende Themen sollten bei zukünftigen Projekten im Bereich Forschung und Entwicklung in Betracht gezogen werden.

- Zusammensetzung und Schädlichkeit übel riechender Emissionen von Anlagen der Nahrungsmittel-, Getränke- und Milchindustrie
- Ermittlung von Techniken zur weiteren Verringerung der niedrigsten NO<sub>x</sub>-Emissionen, die aus der Kaffeeröstung berichtet wurden
- Ermittlung von Alternativen zur Verwendung von EDTA in Reinigungsmitteln und
- Umweltvorteile und Kosten der Umkehrosmose.

Die Europäische Gemeinschaft initiiert und fördert durch ihre FTE-Programme ("Forschung und technologische Entwicklung", 6. Rahmenprogramm der EU für Forschung und technologische Entwicklung) eine Reihe von Vorhaben, die saubere Techniken, neue Abwasseraufbereitungstechniken und Managementstrategien betreffen. Diese Vorhaben können potenziell einen wichtigen Beitrag zu künftigen Überarbeitungen des BVT-Merkblatts leisten. Die Leser werden daher gebeten, das Europäische Büro für integrierte Vermeidung und Verminderung der Umweltverschmutzung EIPPCB über etwaige Forschungsergebnisse zu unterrichten, die im Hinblick auf dieses Dokument relevant sind (siehe auch Vorwort).

## VORWORT

### 1. Status dieses Dokuments

Sofern nicht anders angegeben, beziehen sich alle Hinweise auf „die Richtlinie“ im vorliegenden Dokument auf die Richtlinie 96/61/EG des Rates über die integrierte Vermeidung und Verminderung der Umweltverschmutzung. Wie die Richtlinie berührt auch dieses Dokument nicht die Vorschriften der Gemeinschaft über die Gesundheit und Sicherheit am Arbeitsplatz.

Dieses Dokument ist Teil einer Reihe, in der die Ergebnisse eines Informationsaustauschs zwischen den EU-Mitgliedstaaten und der betroffenen Industrie über beste verfügbare Techniken (BVT), die damit verbundenen Überwachungsmaßnahmen und die Entwicklungen auf diesem Gebiet vorgestellt werden. Es wird von der Europäischen Kommission gemäß Artikel 16 Absatz 2 der Richtlinie veröffentlicht und muss daher gemäß Anhang IV der Richtlinie bei der Festlegung der „besten verfügbaren Techniken“ berücksichtigt werden.

### 2. Rechtliche Pflichten und Definition der BVT gemäß der Richtlinie über die integrierte Vermeidung und Verminderung der Umweltverschmutzung

Um dem Leser das Verständnis des rechtlichen Rahmens zu erleichtern, in dem das vorliegende Dokument ausgearbeitet wurde, werden im Vorwort die wichtigsten Bestimmungen der Richtlinie über die integrierte Vermeidung und Verminderung der Umweltverschmutzung beschrieben und eine Definition des Begriffs „beste verfügbare Techniken“ gegeben. Diese Beschreibung muss zwangsläufig unvollständig sein und dient ausschließlich der Information. Sie hat keine rechtlichen Konsequenzen und ändert oder berührt in keiner Weise die Bestimmungen der Richtlinie.

Die Richtlinie dient der integrierten Vermeidung und Verminderung der Umweltverschmutzung, die durch die im Anhang I aufgeführten Tätigkeiten verursacht wird, damit insgesamt ein hoher Umweltschutz erreicht wird. Die Rechtsgrundlage der Richtlinie bezieht sich auf den Umweltschutz. Bei ihrer Anwendung sollten auch die anderen Ziele der Gemeinschaft, wie die Wettbewerbsfähigkeit der europäischen Industrie, berücksichtigt werden, so dass sie zu einer nachhaltigen Entwicklung beiträgt.

Im Einzelnen sieht sie ein Genehmigungsverfahren für bestimmte Kategorien industrieller Anlagen vor und verlangt sowohl von den Betreibern als auch von den Durchführungsbehörden und sonstigen Einrichtungen eine integrierte, ganzheitliche Betrachtung des Umweltverschmutzungs- und Verbrauchspotenzials der Anlage. Das Gesamtziel dieses integrierten Konzepts muss darin bestehen, das Management und die Kontrolle der industriellen Prozesse so zu verbessern, dass ein hoher Schutz der gesamten Umwelt gewährleistet ist. Von zentraler Bedeutung für dieses Konzept ist das in Artikel 3 verankerte allgemeine Prinzip, nach dem die Betreiber alle geeigneten Vorsorgemaßnahmen gegen Umweltverschmutzungen zu treffen haben, insbesondere durch den Einsatz der besten verfügbaren Techniken, mit deren Hilfe sie ihre Umweltschutzleistungen verbessern können.

Der Begriff „beste verfügbare Techniken“ ist in Artikel 2 Absatz 11 der Richtlinie definiert als „der effizienteste und fortschrittlichste Entwicklungsstand der Tätigkeiten und entsprechenden Betriebsmethoden, der spezielle Techniken als praktisch geeignet erscheinen lässt, grundsätzlich als Grundlage für die Emissionsgrenzwerte zu dienen, um Emissionen in und Auswirkungen auf die gesamte Umwelt allgemein zu vermeiden oder, wenn dies nicht möglich ist, zu vermindern.“ Weiter heißt es in der Begriffsbestimmung in Artikel 2 Absatz 11:

„Techniken“ beinhalten sowohl die angewandte Technologie als auch die Art und Weise, wie die Anlage geplant, gebaut, gewartet, betrieben und stillgelegt wird.

Als „verfügbar“ werden jene Techniken bezeichnet, die in einem Maßstab entwickelt sind, der unter Berücksichtigung des Kosten/Nutzen-Verhältnisses die Anwendung unter in dem betreffenden industriellen Sektor wirtschaftlich und technisch vertretbaren Verhältnissen ermöglicht, gleich, ob diese Techniken innerhalb des betreffenden Mitgliedstaats verwendet oder hergestellt werden, sofern sie zu vertretbaren Bedingungen für den Betreiber zugänglich sind.

Als „beste“ gelten jene Techniken, die am wirksamsten zur Erreichung eines allgemein hohen Schutzes für die Umwelt als Ganzes sind.

Anhang IV der Richtlinie enthält eine Liste von „Punkten, die bei Festlegung der besten verfügbaren Techniken im Allgemeinen wie auch im Einzelfall zu berücksichtigen sind ... unter Berücksichtigung der sich aus einer Maßnahme ergebenden Kosten und ihres Nutzens sowie des Grundsatzes der Vorsorge und Vermeidung“. Diese Punkte schließen jene Informationen ein, die von der Kommission gemäß Artikel 16 Absatz 2 veröffentlicht werden.

Die für die Erteilung von Genehmigungen zuständigen Behörden haben bei der Festlegung der Genehmigungsaufgaben die in Artikel 3 verankerten allgemeinen Prinzipien zu berücksichtigen. Diese Genehmigungsaufgaben müssen Emissionsgrenzwerte enthalten, die gegebenenfalls durch äquivalente Parameter oder technische Maßnahmen erweitert oder ersetzt werden. Entsprechend Artikel 9 Absatz 4 der Richtlinie müssen sich diese Emissionsgrenzwerte, äquivalenten Parameter und technischen Maßnahmen unbeschadet der Einhaltung der Umweltqualitätsnormen auf die besten verfügbaren Techniken stützen, ohne dass die Anwendung einer bestimmten Technik oder Technologie vorgeschrieben wird. Hierbei sind die technische Beschaffenheit der betreffenden Anlage, ihr Standort und die jeweiligen örtlichen Umweltbedingungen zu berücksichtigen. In jedem Fall haben die Genehmigungsaufgaben Vorkehrungen zur weitestgehenden Verminderung weiträumiger oder grenzüberschreitender Umweltverschmutzungen vorzusehen und einen hohen Schutz für die Umwelt als Ganzes sicherzustellen.

Gemäß Artikel 11 der Richtlinie haben die Mitgliedstaaten dafür zu sorgen, dass die zuständigen Behörden die Entwicklungen bei den besten verfügbaren Techniken verfolgen oder darüber informiert sind.

### **3. Ziel des Dokuments**

Entsprechend Artikel 16 Absatz 2 der Richtlinie hat die Kommission „einen Informationsaustausch zwischen den Mitgliedstaaten und der betroffenen Industrie über die besten verfügbaren Techniken, die damit verbundenen Überwachungsmaßnahmen und die Entwicklungen auf diesem Gebiet“ durchzuführen und die Ergebnisse des Informationsaustausches zu veröffentlichen.

Der Zweck des Informationsaustausches ist unter der Erwägung 25 der Richtlinie erläutert, in der es heißt: „Die Entwicklung und der Austausch von Informationen auf Gemeinschaftsebene über die besten verfügbaren Techniken werden dazu beitragen, das Ungleichgewicht auf technologischer Ebene in der Gemeinschaft auszugleichen, die weltweite Verbreitung der in der Gemeinschaft festgesetzten Grenzwerte und der angewandten Techniken zu fördern und die Mitgliedstaaten bei der wirksamen Durchführung dieser Richtlinien zu unterstützen.“

Zur Unterstützung der unter Artikel 16 Absatz 2 vorgesehenen Maßnahmen hat die Kommission (GD Umwelt) ein Informationsaustauschforum (IEF) geschaffen, unter dessen Schirmherrschaft mehrere technische Arbeitsgruppen eingesetzt wurden. Bei diesem Forum und in den technischen Arbeitsgruppen sind, wie in Artikel 16 Absatz 2 verlangt, sowohl die Mitgliedstaaten als auch die Industrie vertreten.

In dieser Dokumentenreihe werden der Informationsaustausch, wie er gemäß Artikel 16 Absatz 2 stattgefunden hat, genau wiedergegeben und der Genehmigungsbehörde Referenzinformationen für die Genehmigungsaufgaben zur Verfügung gestellt. Mit ihren Informationen über die besten verfügbaren Techniken sollen diese Dokumente als ein wertvolles Mittel zur Verbesserung der Umweltschutzleistung dienen.

### **4. Informationsquellen**

Dieses Dokument enthält eine Zusammenfassung von Informationen, die aus verschiedenen Quellen, einschließlich sachkundiger Angaben der zur Unterstützung der Kommission geschaffenen Arbeitsgruppen, stammen und von den Dienststellen der Kommission geprüft wurden. Alle Beiträge werden dankbar anerkannt.

## 5. Anleitung zum Verständnis und zur Benutzung des Dokuments

Die im vorliegenden Dokument enthaltenen Informationen sind als Unterstützung bei der Bestimmung der BVT in speziellen Fällen gedacht. Bei der Bestimmung der BVT und bei den auf BVT basierenden Genehmigungsaufgaben ist stets vom Gesamtziel, d. h. einem hohen Schutz für die Umwelt als Ganzes, auszugehen.

Der verbleibende Teil dieses Abschnitts beschreibt, welche Art von Informationen die einzelnen Kapitel des Dokuments enthalten.

Kapitel 1 und 2 geben allgemeine Informationen über die Branche und über die in der Branche angewandten industriellen Verfahren. Kapitel 3 enthält Daten und Angaben über die Emissions- und Verbrauchswerte bestehender Anlagen. Sie zeigen den Stand zum Zeitpunkt der Erarbeitung des Dokuments.

In Kapitel 4 werden eingehender die Verfahren zur Emissionsverminderung und andere Methoden beschrieben, die als die wichtigsten für die Bestimmung der BVT wie auch für die auf BVT basierenden Genehmigungsaufgaben betrachtet werden. Diese Informationen schließen die Verbrauchs- und Emissionswerte ein, die sich mit dem jeweiligen Verfahren erreichen lassen, einige Vorstellungen über die mit der jeweiligen Technik verbundenen Kosten und die medienübergreifenden Aspekte sowie Angaben über die Anwendbarkeit der Technik in Anlagen, die der IVU-Genehmigung unterliegen, z. B. neue, bestehende, große oder kleine Anlagen. Verfahren, die allgemein als veraltet gelten, wurden nicht berücksichtigt.

In Kapitel 5 werden die Verfahren und die Emissions- und Verbrauchswerte aufgeführt, die allgemein den Anforderungen an die besten verfügbaren Techniken entsprechen. Dabei geht es darum, allgemeine Angaben über die Emissions- und Verbrauchswerte bereitzustellen, die für die auf BVT basierenden Genehmigungsaufgaben oder für allgemein verbindliche Vorschriften gemäß Artikel 9 Absatz 8 als Bezug gelten können. Jedoch muss darauf hingewiesen werden, dass es sich in diesem Dokument nicht um Vorschläge für Emissionsgrenzwerte handelt. Bei den Genehmigungsaufgaben sind lokale, standortspezifische Faktoren wie die technische Beschaffenheit der betreffenden Anlage, ihr Standort und die örtlichen Umweltbedingungen zu berücksichtigen. Ferner ist bei bestehenden Anlagen die wirtschaftliche und technische Vertretbarkeit einer Modernisierung zu beachten. Allein die angestrebte Sicherung eines hohen Schutzes für die Umwelt als Ganzes erfordert nicht selten ein Abwägen der einzelnen Umweltauswirkungen, das wiederum oft von lokalen Erwägungen beeinflusst wird.

Ogleich im vorliegenden Dokument der Versuch unternommen wird, einige dieser Aspekte aufzugreifen, ist eine umfassende Behandlung in diesem Rahmen nicht möglich. Somit sind die in Kapitel 5 aufgeführten Verfahren und Zahlenwerte nicht notwendigerweise auf alle Anlagen anwendbar. Andererseits verlangt die Pflicht zur Sicherung eines hohen Umweltschutzes einschließlich einer weitestgehenden Verminderung der weiträumigen oder grenzüberschreitenden Umweltverschmutzung, dass Genehmigungsaufgaben nicht aus rein lokalen Erwägungen festgesetzt werden. Daher ist die vollständige Berücksichtigung der im vorliegenden Dokument enthaltenen Informationen durch die Genehmigungsbehörden von größter Bedeutung.

Da sich die besten verfügbaren Techniken mit der Zeit ändern, wird dieses Dokument bei Bedarf überprüft und aktualisiert. Stellungnahmen und Vorschläge sind an das Europäische IPPC-Büro beim Institut für technologische Zukunftsforschung zu senden:

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# BVT-Merkblatt zu über die besten verfügbaren Techniken in der Nahrungsmittel-, Getränke- und Milchindustrie

|           |  |     |           |   |      |
|-----------|--|-----|-----------|---|------|
|           | EXECUTIVE SUMMARY.....   | i   |           | ZUSAMMENFASSUNG.....  | i    |
|           | PREFACE.....   | xi  |           | VORWORT .....   | xiii |
|           | SCOPE.....   | xli |           | GELTUNGSBEREICH.....  | lv   |
| 1         | <b>GENERAL INFORMATION</b> .....   | 1   | 1         | ALLGEMEINE  |      |
| 1.1       | <b>Description, turnover, growth, employment</b> .....                                       | 1   | 1.1       | INFORMATIONEN.....  | 1    |
| 1.2       | <b>Sector structure</b> .....  | 3   | 1.2       | Beschreibung, Fluktuation, Wachstum, Beschäftigungszahlen .....   | 1    |
| 1.3       | <b>Trade</b> .....   | 3   | 1.3       | Struktur des Sektors.....   | 3    |
| 1.4       | <b>Market forces: demand, distribution and competition</b> .....                             | 4   | 1.4       | Handel .....  | 3    |
| 1.4.1     | <b>Demand</b> .....  | 4   | 1.4       | Marktkräfte: Nachfrage, Vertrieb und Wettbewerb.....  | 4    |
| 1.4.2     | <b>Distribution</b> .....  | 4   | 1.4.1     | Nachfrage.....  | 4    |
| 1.4.3     | <b>Competition</b> .....   | 4   | 1.4.2     | Vertrieb.....   | 4    |
| 1.5       |  |     | 1.4.3     | Wettbewerb .....  | 4    |
|           | <b>The importance of food safety in FDM processing</b> .....                                 | 4   | 1.5       | Bedeutung der Lebensmittelsicherheit in der Verarbeitung im Nahrungsmittelsektor .....                      | 4    |
| 1.6       | <b>Legislative framework for food, drink and milk products</b> .....                         | 5   | 1.6       | Gesetzlicher Rahmen für Nahrungsmittel, Getränke und Milchprodukte....                                      | 5    |
| 1.7       | <b>The FDM sector and the environment</b> .....  | 5   | 1.7       | Der Nahrungsmittelsektor und die Umwelt .....   | 5    |
| 1.7.1     | <b>Key environmental issues</b> .....  | 6   | 1.7.1     | Wichtige Umweltfragen .....   | 6    |
| 2         | <b>APPLIED PROCESSES AND TECHNIQUES</b> .....  | 9   | 2         | ANGEWANDTE VERFAHREN UND TECHNIKEN.....   | 9    |
| 2.1       | <b>Processing techniques and unit operations</b> .....                                       | 9   | 2.1       | Verarbeitungstechniken und Arbeitsbereiche.....   | 9    |
| 2.1.1     | <b>Materials reception and preparation (A)</b> .....   | 10  | 2.1.1     | Materialannahme und Vorbereitung (A) .....  | 10   |
| 2.1.1.1   | <b>Materials handling and storage (A.1)</b> .....  | 10  | 2.1.1.1   | Materialhandhabung und -lagerung (A.1) .....  | 10   |
| 2.1.1.1.1 | <b>Objective</b> .....   | 10  | 2.1.1.1.1 | Zielsetzung .....   | 10   |
| 2.1.1.1.2 | <b>Field of application</b> .....  | 10  | 2.1.1.1.2 | Anwendungsbereich .....   | 10   |
| 2.1.1.1.3 | <b>Description of techniques, methods and equipment</b> .....                                | 11  | 2.1.1.1.3 | Beschreibung von Techniken, Methoden und Geräten .....  | 11   |
| 2.1.1.2   | <b>Sorting/screening, grading, dehulling, destemming/destalking and trimming (A.2)</b> ..... | 11  | 2.1.1.2   | Sortieren/Sieben, Klassifizieren, Enthülsen, Entfernen von Stielen/Stämmen und Zurechtschneiden (A.2) ..... | 11   |
| 2.1.1.2.1 | <b>Objective</b> .....   | 11  | 2.1.1.2.1 | Zielsetzung .....   | 11   |
| 2.1.1.2.2 | <b>Field of application</b> .....  | 11  | 2.1.1.2.2 | Anwendungsbereich .....   | 11   |
| 2.1.1.2.3 | <b>Description of techniques, methods and equipment</b> .....                                | 11  | 2.1.1.2.3 | Beschreibung von Techniken, Methoden und Geräten .....  | 11   |
| 2.1.1.3   | <b>Peeling (A.3)</b> .....   | 12  | 2.1.1.3   | Schälen (A.3).....  | 12   |
| 2.1.1.3.1 | <b>Objective</b> .....   | 12  | 2.1.1.3.1 | Zielsetzung .....   | 12   |
| 2.1.1.3.2 | <b>Field of application</b> .....  | 12  | 2.1.1.3.2 | Anwendungsbereich .....   | 12   |
| 2.1.1.3.3 | <b>Description of techniques, methods and equipment</b> .....                                | 12  | 2.1.1.3.3 | Beschreibung von Techniken, Methoden und Geräten .....  | 12   |
| 2.1.1.4   | <b>Washing (A.4)</b> .....   | 12  | 2.1.1.4   | Waschen (A.4).....  | 12   |
| 2.1.1.4.1 | <b>Objective</b> .....   | 12  | 2.1.1.4.1 | Zielsetzung .....   | 12   |
| 2.1.1.4.2 | <b>Field of application</b> .....  | 13  | 2.1.1.4.2 | Anwendungsbereich .....   | 13   |
| 2.1.1.4.3 | <b>Description of techniques, methods and equipment</b> .....                                | 13  | 2.1.1.4.3 | Beschreibung von Techniken, Methoden und Geräten .....  | 13   |
| 2.1.1.5   | <b>Thawing (A.5)</b> .....   | 13  | 2.1.1.5   | Auftauen (A.5).....   | 13   |
| 2.1.1.5.1 | <b>Objective</b> .....   | 13  | 2.1.1.5.1 | Zielsetzung .....   | 13   |
| 2.1.1.5.2 | <b>Field of application</b> .....  | 13  | 2.1.1.5.2 | Anwendungsbereich .....   | 13   |
| 2.1.1.5.3 | <b>Description of techniques, methods and equipment</b> .....                                | 13  | 2.1.1.5.3 | Beschreibung von Techniken, Methoden und Geräten .....  | 13   |

|           |  |    |           |   |    |
|-----------|--|----|-----------|---|----|
| 2.1.2     | <b>Size reduction, mixing and forming (B)</b> .....                          | 13 | 2.1.2     | Zerkleinern, Mischen und Formen (B).....                                  | 13 |
| 2.1.2.1   | <b>Cutting, slicing, chopping, mincing, pulping and pressing (B.1)</b> ..... | 13 | 2.1.2.1   | Zerteilen, Schneiden, Zerhacken, Mahlen, Quetschen und Pressen (B.1)..... | 13 |
| 2.1.2.1.1 | <b>Objective</b> .....   | 13 | 2.1.2.1.1 | Zielsetzung.....  | 13 |
| 2.1.2.1.2 | <b>Field of application</b> .....  | 13 | 2.1.2.1.2 | Anwendungsbereich.....  | 13 |
| 2.1.2.1.3 | <b>Description of techniques, methods and equipment</b> .....                | 14 | 2.1.2.1.3 | Beschreibung von Techniken, Methoden und Geräten.....                     | 14 |
| 2.1.2.2   | <b>Mixing/blending, homogenisation and conching (B.2)</b> .....              | 15 | 2.1.2.2   | Mischen/Verschneiden, Homogenisieren und Conchieren (B.2).....            | 15 |
| 2.1.2.2.1 | <b>Objective</b> .....   | 15 | 2.1.2.2.1 | Zielsetzung.....  | 15 |
| 2.1.2.2.2 | <b>Field of application</b> .....  | 15 | 2.1.2.2.2 | Anwendungsbereich.....  | 15 |
| 2.1.2.2.3 | <b>Description of techniques, methods and equipment</b> .....                | 15 | 2.1.2.2.3 | Beschreibung von Techniken, Methoden und Geräten.....                     | 15 |
| 2.1.2.3   | <b>Grinding/milling and crushing (B.3)</b> .....                             | 16 | 2.1.2.3   | Schroten/Mahlen und Zerstoßen (B.3).....                                  | 16 |
| 2.1.2.3.1 | <b>Objective</b> .....   | 16 | 2.1.2.3.1 | Zielsetzung.....  | 16 |
| 2.1.2.3.2 | <b>Field of application</b> .....  | 16 | 2.1.2.3.2 | Anwendungsbereich.....  | 16 |
| 2.1.2.3.3 | <b>Description of processing techniques, methods and equipment</b> .....     | 16 | 2.1.2.3.3 | Beschreibung von Verarbeitungstechniken, Methoden und Geräten.....        | 16 |
| 2.1.2.4   | <b>Forming/moulding and extruding (B.4)</b> .....                            | 16 | 2.1.2.4   | Formen und Extrudieren (B.4).....   | 16 |
| 2.1.2.4.1 | <b>Objective</b> .....   | 16 | 2.1.2.4.1 | Zielsetzung.....  | 16 |
| 2.1.2.4.2 | <b>Field of application</b> .....  | 16 | 2.1.2.4.2 | Anwendungsbereich.....  | 16 |
| 2.1.2.4.3 | <b>Description of techniques, methods and equipment</b> .....                | 17 | 2.1.2.4.3 | Beschreibung von Techniken, Methoden und Geräten.....                     | 17 |
| 2.1.3     | <b>Separation techniques (C)</b> .....                                       | 17 | 2.1.3     | Trenn- und Abscheidetechniken (C) ...                                     | 17 |
| 2.1.3.1   | <b>Extraction (C.1)</b> .....  | 17 | 2.1.3.1   | Extraktion (C.1).....   | 17 |
| 2.1.3.1.1 | <b>Objective</b> .....   | 17 | 2.1.3.1.1 | Zielsetzung.....  | 17 |
| 2.1.3.1.2 | <b>Field of application</b> .....  | 17 | 2.1.3.1.2 | Anwendungsbereich.....  | 17 |
| 2.1.3.1.3 | <b>Description of techniques, methods and equipment</b> .....                | 17 | 2.1.3.1.3 | Beschreibung von Techniken, Methoden und Geräten.....                     | 17 |
| 2.1.3.2   | <b>Deionisation (C.2)</b> .....  | 18 | 2.1.3.2   | Deionisation (C.2).....   | 18 |
| 2.1.3.2.1 | <b>Objective</b> .....   | 18 | 2.1.3.2.1 | Zielsetzung.....  | 18 |
| 2.1.3.2.2 | <b>Field of application</b> .....  | 18 | 2.1.3.2.2 | Anwendungsbereich.....  | 18 |
| 2.1.3.2.3 | <b>Description of techniques, methods and equipment</b> .....                | 18 | 2.1.3.2.3 | Beschreibung von Techniken, Methoden und Geräten.....                     | 18 |
| 2.1.3.3   | <b>Fining (C.3)</b> .....  | 18 | 2.1.3.3   | Klären (C.3).....   | 18 |
| 2.1.3.3.1 | <b>Objective</b> .....   | 18 | 2.1.3.3.1 | Zielsetzung.....  | 18 |
| 2.1.3.3.2 | <b>Field of application</b> .....  | 18 | 2.1.3.3.2 | Anwendungsbereich.....  | 18 |
| 2.1.3.3.3 | <b>Description of techniques, methods and equipment</b> .....                | 18 | 2.1.3.3.3 | Beschreibung von Techniken, Methoden und Geräten.....                     | 18 |
| 2.1.3.4   | <b>Centrifugation and sedimentation (C.4)</b> .....                          | 19 | 2.1.3.4   | Zentrifugieren und Sedimentieren (C.4).....                               | 19 |
| 2.1.3.4.1 | <b>Objective</b> .....   | 19 | 2.1.3.4.1 | Zielsetzung.....  | 19 |
| 2.1.3.4.2 | <b>Field of application</b> .....  | 19 | 2.1.3.4.2 | Anwendungsbereich.....  | 19 |
| 2.1.3.4.3 | <b>Description of techniques, methods and equipment</b> .....                | 19 | 2.1.3.4.3 | Beschreibung von Techniken, Methoden und Geräten.....                     | 19 |
| 2.1.3.5   | <b>Filtration (C.5)</b> .....  | 20 | 2.1.3.5   | Filtrieren (C.5).....   | 20 |
| 2.1.3.5.1 | <b>Objective</b> .....   | 20 | 2.1.3.5.1 | Zielsetzung.....  | 20 |
| 2.1.3.5.2 | <b>Field of application</b> .....  | 20 | 2.1.3.5.2 | Anwendungsbereich.....  | 20 |
| 2.1.3.5.3 | <b>Description of techniques, methods and equipment</b> .....                | 20 | 2.1.3.5.3 | Beschreibung von Techniken, Methoden und Geräten.....                     | 20 |
| 2.1.3.6   | <b>Membrane separation (C.6)</b> .....                                       | 21 | 2.1.3.6   | Membrantrennverfahren (C.6).....  | 21 |
| 2.1.3.6.1 | <b>Objective</b> .....   | 21 | 2.1.3.6.1 | Zielsetzung.....  | 21 |
| 2.1.3.6.2 | <b>Field of application</b> .....  | 21 | 2.1.3.6.2 | Anwendungsbereich.....  | 21 |
| 2.1.3.6.3 | <b>Description of techniques, methods and equipment</b> .....                | 22 | 2.1.3.6.3 | Beschreibung von Techniken, Methoden und Geräten.....                     | 22 |
| 2.1.3.7   | <b>Crystallisation (C.7)</b> .....   | 22 | 2.1.3.7   | Kristallisation (C.7).....  | 22 |
| 2.1.3.7.1 | <b>Objective</b> .....   | 22 | 2.1.3.7.1 | Zielsetzung.....  | 22 |

|            |  |    |            |   |    |
|------------|--|----|------------|---|----|
| 2.1.3.7.2  | <b>Field of application.....</b>   | 22 | 2.1.3.7.2  | Anwendungsbereich .....   | 22 |
| 2.1.3.7.3  | <b>Description of the technique, methods and equipment.....</b>          | 22 | 2.1.3.7.3  | Beschreibung von Techniken, Methoden und Geräten .....              | 22 |
| 2.1.3.8    | <b>Removal of free fatty acids (ffa) by neutralisation (C.8) .....</b>   | 22 | 2.1.3.8    | Beseitigen freier Fettsäuren durch Neutralisation (C.8) .....       | 22 |
| 2.1.3.8.1  | <b>Objective .....</b>   | 22 | 2.1.3.8.1  | Zielsetzung .....   | 22 |
| 2.1.3.8.2  | <b>Field of application.....</b>   | 23 | 2.1.3.8.2  | Anwendungsbereich .....   | 23 |
| 2.1.3.8.3  | <b>Description of techniques, methods and equipment.....</b>             | 23 | 2.1.3.8.3  | Beschreibung von Techniken, Methoden und Geräten .....              | 23 |
| 2.1.3.9    | <b>Bleaching (C.9) .....</b>   | 23 | 2.1.3.9    | Bleichen (C.9).....   | 23 |
| 2.1.3.9.1  | <b>Objective .....</b>   | 23 | 2.1.3.9.1  | Zielsetzung .....   | 23 |
| 2.1.3.9.2  | <b>Field of application.....</b>   | 23 | 2.1.3.9.2  | Anwendungsbereich .....   | 23 |
| 2.1.3.9.3  | <b>Description of techniques, methods and equipment.....</b>             | 24 | 2.1.3.9.3  | Beschreibung von Techniken, Methoden und Geräten .....              | 24 |
| 2.1.3.10   | <b>Deodorisation by steam stripping (C.10).....</b>                      | 24 | 2.1.3.10   | Desodorieren durch Dampf-Stripping (C.10).....                      | 24 |
| 2.1.3.10.1 | <b>Objective .....</b>   | 24 | 2.1.3.10.1 | Zielsetzung .....   | 24 |
| 2.1.3.10.2 | <b>Field of application.....</b>   | 24 | 2.1.3.10.2 | Anwendungsbereich .....   | 24 |
| 2.1.3.10.3 | <b>Description of techniques, methods and equipment.....</b>             | 24 | 2.1.3.10.3 | Beschreibung von Techniken, Methoden und Geräten .....              | 24 |
| 2.1.3.11   | <b>Decolourisation (C.11) .....</b>                                      | 24 | 2.1.3.11   | Entfärben (C.11).....   | 24 |
| 2.1.3.11.1 | <b>Objective .....</b>   | 24 | 2.1.3.11.1 | Zielsetzung .....   | 24 |
| 2.1.3.11.2 | <b>Field of application.....</b>   | 24 | 2.1.3.11.2 | Anwendungsbereich .....   | 24 |
| 2.1.3.11.3 | <b>Description of techniques, methods and equipment.....</b>             | 24 | 2.1.3.11.3 | Beschreibung von Techniken, Methoden und Geräten .....              | 24 |
| 2.1.3.12   | <b>Distillation (C.12) .....</b>   | 25 | 2.1.3.12   | Destillation (C12) .....  | 25 |
| 2.1.3.12.1 | <b>Objective .....</b>   | 25 | 2.1.3.12.1 | Zielsetzung .....   | 25 |
| 2.1.3.12.2 | <b>Field of application.....</b>   | 25 | 2.1.3.12.2 | Anwendungsbereich .....   | 25 |
| 2.1.3.12.3 | <b>Description of techniques, methods and equipment.....</b>             | 25 | 2.1.3.12.3 | Beschreibung von Techniken, Methoden und Geräten .....              | 25 |
| 2.1.4      | <b>Product processing technology (D)..</b>                               | 26 | 2.1.4      | Produktverarbeitungstechnik (D).....                                | 26 |
| 2.1.4.1    | <b>Soaking (D.1) .....</b>   | 26 | 2.1.4.1    | Einweichen (D.1).....   | 26 |
| 2.1.4.1.1  | <b>Objective .....</b>   | 26 | 2.1.4.1.1  | Zielsetzung .....   | 26 |
| 2.1.4.1.2  | <b>Field of application.....</b>   | 26 | 2.1.4.1.2  | Anwendungsbereich .....   | 26 |
| 2.1.4.1.3  | <b>Description of techniques, methods and equipment.....</b>             | 26 | 2.1.4.1.3  | Beschreibung von Techniken, Methoden und Geräten .....              | 26 |
| 2.1.4.2    | <b>Dissolving (D.2) .....</b>  | 27 | 2.1.4.2    | Auflösen (D.2).....   | 27 |
| 2.1.4.2.1  | <b>Objective .....</b>   | 27 | 2.1.4.2.1  | Zielsetzung .....   | 27 |
| 2.1.4.2.2  | <b>Field of application.....</b>   | 27 | 2.1.4.2.2  | Anwendungsbereich .....   | 27 |
| 2.1.4.2.3  | <b>Description of techniques, methods and equipment.....</b>             | 27 | 2.1.4.2.3  | Beschreibung von Techniken, Methoden und Geräten .....              | 27 |
| 2.1.4.3    | <b>Solubilisation/alkalising (D.3) .....</b>                             | 27 | 2.1.4.3    | Solubilisation/Alkalisieren (D.3).....                              | 27 |
| 2.1.4.3.1  | <b>Objective .....</b>   | 27 | 2.1.4.3.1  | Zielsetzung .....   | 27 |
| 2.1.4.3.2  | <b>Field of application.....</b>   | 27 | 2.1.4.3.2  | Anwendungsbereich .....   | 27 |
| 2.1.4.3.3  | <b>Description of techniques, methods and equipment.....</b>             | 27 | 2.1.4.3.3  | Beschreibung von Techniken, Methoden und Geräten .....              | 27 |
| 2.1.4.4    | <b>Fermentation (D.4).....</b>   | 28 | 2.1.4.4    | Fermentation (D.4) .....  | 28 |
| 2.1.4.4.1  | <b>Objective .....</b>   | 28 | 2.1.4.4.1  | Zielsetzung .....   | 28 |
| 2.1.4.4.2  | <b>Field of application.....</b>   | 28 | 2.1.4.4.2  | Anwendungsbereich .....   | 28 |
| 2.1.4.4.3  | <b>Description of techniques, methods and equipment.....</b>             | 28 | 2.1.4.4.3  | Beschreibung von Techniken, Methoden und Geräten .....              | 28 |
| 2.1.4.5    | <b>Coagulation (D.5) .....</b>   | 29 | 2.1.4.5    | Koagulation (D.5).....  | 29 |
| 2.1.4.5.1  | <b>Objective .....</b>   | 29 | 2.1.4.5.1  | Zielsetzung .....   | 29 |
| 2.1.4.5.2  | <b>Field of application.....</b>   | 29 | 2.1.4.5.2  | Anwendungsbereich .....   | 29 |
| 2.1.4.5.3  | <b>Description of technique, methods and equipment.....</b>              | 29 | 2.1.4.5.3  | Beschreibung von Techniken, Methoden und Geräten .....              | 29 |
| 2.1.4.6    | <b>Germination (D.6) .....</b>   | 29 | 2.1.4.6    | Keimung (D.6).....  | 29 |
| 2.1.4.6.1  | <b>Objective .....</b>   | 29 | 2.1.4.6.1  | Zielsetzung .....   | 29 |
| 2.1.4.6.2  | <b>Field of application.....</b>   | 29 | 2.1.4.6.2  | Anwendungsbereich .....   | 29 |
| 2.1.4.6.3  | <b>Description of processing techniques, methods and equipment .....</b> | 30 | 2.1.4.6.3  | Beschreibung von Verarbeitungstechniken, Methoden und Geräten ..... | 30 |

|            |  |    |            |   |    |
|------------|--|----|------------|---|----|
| 2.1.4.7    | <b>Brining/curing and pickling (D.7) ....</b>                              | 30 | 2.1.4.7    | <b>Einpökeln/Einsalzen und Einlegen (D.7).....</b>                      | 30 |
| 2.1.4.7.1  | <b>Objective .....</b>   | 30 | 2.1.4.7.1  | <b>Zielsetzung.....</b>   | 30 |
| 2.1.4.7.2  | <b>Field of application.....</b>   | 30 | 2.1.4.7.2  | <b>Anwendungsbereich.....</b>   | 30 |
| 2.1.4.7.3  | <b>Description of techniques, methods and equipment.....</b>               | 30 | 2.1.4.7.3  | <b>Beschreibung von Techniken, Methoden und Geräten.....</b>            | 30 |
| 2.1.4.8    | <b>Smoking (D.8) .....</b>   | 31 | 2.1.4.8    | <b>Räuchern (D.8).....</b>  | 31 |
| 2.1.4.8.1  | <b>Objective .....</b>   | 31 | 2.1.4.8.1  | <b>Zielsetzung.....</b>   | 31 |
| 2.1.4.8.2  | <b>Field of application.....</b>   | 31 | 2.1.4.8.2  | <b>Anwendungsbereich.....</b>   | 31 |
| 2.1.4.8.3  | <b>Description of techniques, methods and equipment.....</b>               | 31 | 2.1.4.8.3  | <b>Beschreibung von Techniken, Methoden und Geräten.....</b>            | 31 |
| 2.1.4.9    | <b>Hardening (D.9).....</b>  | 31 | 2.1.4.9    | <b>Härten (D.9).....</b>  | 31 |
| 2.1.4.9.1  | <b>Objective .....</b>   | 31 | 2.1.4.9.1  | <b>Zielsetzung.....</b>   | 31 |
| 2.1.4.9.2  | <b>Field of application.....</b>   | 32 | 2.1.4.9.2  | <b>Anwendungsbereich.....</b>   | 32 |
| 2.1.4.9.3  | <b>Description of techniques, methods and equipment.....</b>               | 32 | 2.1.4.9.3  | <b>Beschreibung von Techniken, Methoden und Geräten.....</b>            | 32 |
| 2.1.4.10   | <b>Sulphitation (D.10) .....</b>   | 32 | 2.1.4.10   | <b>Sulfitieren (D.10).....</b>  | 32 |
| 2.1.4.10.1 | <b>Objective .....</b>   | 32 | 2.1.4.10.1 | <b>Zielsetzung.....</b>   | 32 |
| 2.1.4.10.2 | <b>Field of application.....</b>   | 32 | 2.1.4.10.2 | <b>Anwendungsbereich.....</b>   | 32 |
| 2.1.4.10.3 | <b>Description of techniques, methods and equipment.....</b>               | 32 | 2.1.4.10.3 | <b>Beschreibung von Techniken, Methoden und Geräten.....</b>            | 32 |
| 2.1.4.11   | <b>Carbonatation (D.11) .....</b>  | 32 | 2.1.4.11   | <b>Carbonatation (D.11) .....</b>                                       | 32 |
| 2.1.4.11.1 | <b>Objective .....</b>   | 32 | 2.1.4.11.1 | <b>Zielsetzung.....</b>   | 32 |
| 2.1.4.11.2 | <b>Field of application.....</b>   | 32 | 2.1.4.11.2 | <b>Anwendungsbereich.....</b>   | 32 |
| 2.1.4.11.3 | <b>Description of techniques, methods and equipment.....</b>               | 33 | 2.1.4.11.3 | <b>Beschreibung von Techniken, Methoden und Geräten.....</b>            | 33 |
| 2.1.4.12   | <b>Carbonation (D.12).....</b>   | 33 | 2.1.4.12   | <b>Versetzen mit Kohlensäure (D.12).....</b>                            | 33 |
| 2.1.4.12.1 | <b>Objective .....</b>   | 33 | 2.1.4.12.1 | <b>Zielsetzung.....</b>   | 33 |
| 2.1.4.12.2 | <b>Field of application.....</b>   | 33 | 2.1.4.12.2 | <b>Anwendungsbereich.....</b>   | 33 |
| 2.1.4.12.3 | <b>Description of techniques, methods and equipment.....</b>               | 33 | 2.1.4.12.3 | <b>Beschreibung von Techniken, Methoden und Geräten.....</b>            | 33 |
| 2.1.4.13   | <b>Coating/spraying/enrobing/agglo meration/encapsulation (D.13) .....</b> | 34 | 2.1.4.13   | <b>Beschichten/Besprühen/ Einkleiden/Sintern/Einkapseln (D.13).....</b> | 34 |
| 2.1.4.13.1 | <b>Objective .....</b>   | 34 | 2.1.4.13.1 | <b>Zielsetzung.....</b>   | 34 |
| 2.1.4.13.2 | <b>Field of application.....</b>   | 34 | 2.1.4.13.2 | <b>Anwendungsbereich.....</b>   | 34 |
| 2.1.4.13.3 | <b>Description of techniques, methods and equipment.....</b>               | 34 | 2.1.4.13.3 | <b>Beschreibung von Techniken, Methoden und Geräten.....</b>            | 34 |
| 2.1.4.14   | <b>Ageing (D.14) .....</b>   | 34 | 2.1.4.14   | <b>Reifung (D.14).....</b>  | 34 |
| 2.1.4.14.1 | <b>Objective .....</b>   | 34 | 2.1.4.14.1 | <b>Zielsetzung.....</b>   | 34 |
| 2.1.4.14.2 | <b>Field of application.....</b>   | 34 | 2.1.4.14.2 | <b>Anwendungsbereich.....</b>   | 34 |
| 2.1.4.14.3 | <b>Description of techniques, methods and equipment.....</b>               | 34 | 2.1.4.14.3 | <b>Beschreibung von Techniken, Methoden und Geräten.....</b>            | 34 |
| 2.1.5      | <b>Heat processing (E) .....</b>   | 35 | 2.1.5      | <b>Wärmebehandlung (E).....</b>   | 35 |
| 2.1.5.1    | <b>Melting (E.1) .....</b>   | 35 | 2.1.5.1    | <b>Schmelzen (E.1).....</b>   | 35 |
| 2.1.5.1.1  | <b>Objective .....</b>   | 35 | 2.1.5.1.1  | <b>Zielsetzung.....</b>   | 35 |
| 2.1.5.1.2  | <b>Field of application.....</b>   | 35 | 2.1.5.1.2  | <b>Anwendungsbereich.....</b>   | 35 |
| 2.1.5.1.3  | <b>Description of techniques, methods and equipment.....</b>               | 35 | 2.1.5.1.3  | <b>Beschreibung von Techniken, Methoden und Geräten.....</b>            | 35 |
| 2.1.5.2    | <b>Blanching (E.2) .....</b>   | 35 | 2.1.5.2    | <b>Blanchieren (E.2).....</b>   | 35 |
| 2.1.5.2.1  | <b>Objective .....</b>   | 35 | 2.1.5.2.1  | <b>Zielsetzung.....</b>   | 35 |
| 2.1.5.2.2  | <b>Field of application.....</b>   | 35 | 2.1.5.2.2  | <b>Anwendungsbereich.....</b>   | 35 |
| 2.1.5.2.3  | <b>Description of techniques, methods and equipment.....</b>               | 35 | 2.1.5.2.3  | <b>Beschreibung von Techniken, Methoden und Geräten.....</b>            | 35 |
| 2.1.5.3    | <b>Cooking and boiling (E.3) .....</b>                                     | 35 | 2.1.5.3    | <b>Garen und Kochen (E.3) .....</b>                                     | 35 |
| 2.1.5.3.1  | <b>Objective .....</b>   | 35 | 2.1.5.3.1  | <b>Zielsetzung .....</b>  | 35 |
| 2.1.5.3.2  | <b>Field of application.....</b>   | 36 | 2.1.5.3.2  | <b>Anwendungsbereich.....</b>   | 36 |
| 2.1.5.3.3  | <b>Description of techniques, methods and equipment.....</b>               | 36 | 2.1.5.3.3  | <b>Beschreibung von Techniken, Methoden und Geräten.....</b>            | 36 |
| 2.1.5.4    | <b>Baking (E.4) .....</b>  | 36 | 2.1.5.4    | <b>Backen (E.4) .....</b>   | 36 |
| 2.1.5.4.1  | <b>Objective .....</b>   | 36 | 2.1.5.4.1  | <b>Zielsetzung.....</b>   | 36 |
| 2.1.5.4.2  | <b>Field of application.....</b>   | 36 | 2.1.5.4.2  | <b>Anwendungsbereich.....</b>   | 36 |

|           |   |    |           |  |    |
|-----------|---|----|-----------|--|----|
| 2.1.5.4.3 | <b>Description of techniques, methods and equipment.....</b>  | 36 | 2.1.5.4.3 | Beschreibung von Techniken, Methoden und Geräten .....         | 36 |
| 2.1.5.5   | <b>Roasting (E.5).....</b>                                    | 37 | 2.1.5.5   | Rösten (E.5).....  | 37 |
| 2.1.5.5.1 | <b>Objective .....</b>  | 37 | 2.1.5.5.1 | Zielsetzung .....  | 37 |
| 2.1.5.5.2 | <b>Field of application.....</b>                              | 37 | 2.1.5.5.2 | Anwendungsbereich .....  | 37 |
| 2.1.5.5.3 | <b>Description of techniques, methods and equipment.....</b>  | 37 | 2.1.5.5.3 | Beschreibung von Techniken, Methoden und Geräten .....         | 37 |
| 2.1.5.6   | <b>Frying (E.6).....</b>                                      | 38 | 2.1.5.6   | Braten/Frittieren (E.6) .....                                  | 38 |
| 2.1.5.6.1 | <b>Objective .....</b>  | 38 | 2.1.5.6.1 | Zielsetzung .....  | 38 |
| 2.1.5.6.2 | <b>Field of application.....</b>                              | 38 | 2.1.5.6.2 | Anwendungsbereich .....  | 38 |
| 2.1.5.6.3 | <b>Description of techniques, methods and equipment.....</b>  | 38 | 2.1.5.6.3 | Beschreibung von Techniken, Methoden und Geräten .....         | 38 |
| 2.1.5.7   | <b>Tempering (E.7) .....</b>                                  | 38 | 2.1.5.7   | Temperieren (E.7).....   | 38 |
| 2.1.5.7.1 | <b>Objective .....</b>  | 38 | 2.1.5.7.1 | Zielsetzung .....  | 38 |
| 2.1.5.7.2 | <b>Field of application.....</b>                              | 38 | 2.1.5.7.2 | Anwendungsbereich .....  | 38 |
| 2.1.5.7.3 | <b>Description of techniques, methods and equipment .....</b> | 39 | 2.1.5.7.3 | Beschreibung von Techniken, Methoden und Geräten .....         | 39 |
| 2.1.5.8   | <b>Pasteurisation, sterilisation and UHT (E.8).....</b>       | 39 | 2.1.5.8   | Pasteurisieren, Sterilisieren und Ultrahoherhitzen (E.8) ..... | 39 |
| 2.1.5.8.1 | <b>Objective .....</b>  | 39 | 2.1.5.8.1 | Zielsetzung .....  | 39 |
| 2.1.5.8.2 | <b>Field of application.....</b>                              | 39 | 2.1.5.8.2 | Anwendungsbereich .....  | 39 |
| 2.1.5.8.3 | <b>Description of techniques, methods and equipment.....</b>  | 40 | 2.1.5.8.3 | Beschreibung von Techniken, Methoden und Geräten .....         | 40 |
| 2.1.6     | <b>Concentration by heat (F) .....</b>                        | 41 | 2.1.6     | Aufkonzentrieren durch Wärme (F) ....                          | 41 |
| 2.1.6.1   | <b>Evaporation (liquid to liquid) (F.1) .....</b>             | 41 | 2.1.6.1   | Verdampfung (flüssig nach flüssig) (F.1) .....                 | 41 |
| 2.1.6.1.1 | <b>Objective .....</b>  | 41 | 2.1.6.1.1 | Zielsetzung .....  | 41 |
| 2.1.6.1.2 | <b>Field of application.....</b>                              | 41 | 2.1.6.1.2 | Anwendungsbereich .....  | 41 |
| 2.1.6.1.3 | <b>Description of techniques, methods and equipment.....</b>  | 41 | 2.1.6.1.3 | Beschreibung von Techniken, Methoden und Geräten .....         | 41 |
| 2.1.6.2   | <b>Drying (liquid to solid) (F.2).....</b>                    | 42 | 2.1.6.2   | Trocknung (flüssig nach trocken) (F.2).....                    | 42 |
| 2.1.6.2.1 | <b>Objective .....</b>  | 42 | 2.1.6.2.1 | Zielsetzung .....  | 42 |
| 2.1.6.2.2 | <b>Field of application.....</b>                              | 42 | 2.1.6.2.2 | Anwendungsbereich .....  | 42 |
| 2.1.6.2.3 | <b>Description of techniques, methods and equipment.....</b>  | 42 | 2.1.6.2.3 | Beschreibung von Techniken, Methoden und Geräten .....         | 42 |
| 2.1.6.3   | <b>Dehydration (solid to solid) (F.3) .....</b>               | 43 | 2.1.6.3   | Dehydration (fest nach fest) (F.3).....                        | 43 |
| 2.1.6.3.1 | <b>Objective .....</b>  | 43 | 2.1.6.3.1 | Zielsetzung .....  | 43 |
| 2.1.6.3.2 | <b>Field of application.....</b>                              | 43 | 2.1.6.3.2 | Anwendungsbereich .....  | 43 |
| 2.1.6.3.3 | <b>Description of techniques, methods and equipment.....</b>  | 43 | 2.1.6.3.3 | Beschreibung von Techniken, Methoden und Geräten .....         | 43 |
| 2.1.7     | <b>Processing by the removal of heat (G).....</b>             | 45 | 2.1.7     | Verarbeitung durch Wärmeentzug (G) .....                       | 45 |
| 2.1.7.1   | <b>Cooling, chilling and cold stabilisation (G.1) .....</b>   | 45 | 2.1.7.1   | Kühlen, Abkühlen und Kältestabilisation (G.1).....             | 45 |
| 2.1.7.1.1 | <b>Objective .....</b>  | 45 | 2.1.7.1.1 | Zielsetzung .....  | 45 |
| 2.1.7.1.2 | <b>Field of application.....</b>                              | 45 | 2.1.7.1.2 | Anwendungsbereich .....  | 45 |
| 2.1.7.1.3 | <b>Description of techniques, methods and equipment.....</b>  | 45 | 2.1.7.1.3 | Beschreibung von Techniken, Methoden und Geräten .....         | 45 |
| 2.1.7.2   | <b>Freezing (G.2).....</b>                                    | 46 | 2.1.7.2   | Tiefkühlen (G.2).....  | 46 |
| 2.1.7.2.1 | <b>Objective .....</b>  | 46 | 2.1.7.2.1 | Zielsetzung .....  | 46 |
| 2.1.7.2.2 | <b>Field of application.....</b>                              | 46 | 2.1.7.2.2 | Anwendungsbereich .....  | 46 |
| 2.1.7.2.3 | <b>Description of techniques, methods and equipment.....</b>  | 46 | 2.1.7.2.3 | Beschreibung von Techniken, Methoden und Geräten .....         | 46 |
| 2.1.7.3   | <b>Freeze-drying/lyophilisation (G.3)...</b>                  | 47 | 2.1.7.3   | Gefriertrocknen/Lyophilisation (G.3)..                         | 47 |
| 2.1.7.3.1 | <b>Objective .....</b>  | 47 | 2.1.7.3.1 | Zielsetzung .....  | 47 |
| 2.1.7.3.2 | <b>Field of application.....</b>                              | 48 | 2.1.7.3.2 | Anwendungsbereich .....  | 48 |
| 2.1.7.3.3 | <b>Description of techniques, methods and equipment.....</b>  | 48 | 2.1.7.3.3 | Beschreibung von Techniken, Methoden und Geräten .....         | 48 |
| 2.1.8     | <b>Post processing operations (H).....</b>                    | 48 | 2.1.8     | Nachbearbeitungsschritte (H).....                              | 48 |
| 2.1.8.1   | <b>Packing and filling (H.1).....</b>                         | 48 | 2.1.8.1   | Verpacken und Befüllen (H.1).....                              | 48 |
| 2.1.8.1.1 | <b>Objective .....</b>  | 48 | 2.1.8.1.1 | Zielsetzung .....  | 48 |
| 2.1.8.1.2 | <b>Field of application.....</b>                              | 48 | 2.1.8.1.2 | Anwendungsbereich .....  | 48 |

|           |   |    |           |   |    |
|-----------|---|----|-----------|---|----|
| 2.1.8.1.3 | <b>Description of techniques, methods and equipment</b> .....     | 49 | 2.1.8.1.3 | Beschreibung von Techniken, Methoden und Geräten.....       | 49 |
| 2.1.8.2   | <b>Gas flushing and storage under gas (H.2)</b> .....             | 50 | 2.1.8.2   | Gasspülung und Lagerung unter Gas (H.2).....                | 50 |
| 2.1.8.2.1 | <b>Objective</b> .....  | 50 | 2.1.8.2.1 | Zielsetzung.....  | 50 |
| 2.1.8.2.2 | <b>Field of application</b> .....                                 | 51 | 2.1.8.2.2 | Anwendungsbereich.....                                      | 51 |
| 2.1.8.2.3 | <b>Description of techniques, methods and equipment</b> .....     | 51 | 2.1.8.2.3 | Beschreibung von Techniken, Methoden und Geräten.....       | 51 |
| 2.1.9     | <b>Utility processes (U)</b> .....                                | 51 | 2.1.9     | Hilfsverfahren (U).....                                     | 51 |
| 2.1.9.1   | <b>Cleaning and disinfection (U.1)</b> .....                      | 51 | 2.1.9.1   | Reinigung und Desinfektion (U.1).....                       | 51 |
| 2.1.9.1.1 | <b>Objective</b> .....  | 51 | 2.1.9.1.1 | Zielsetzung.....  | 51 |
| 2.1.9.1.2 | <b>Field of application</b> .....                                 | 51 | 2.1.9.1.2 | Anwendungsbereich.....                                      | 51 |
| 2.1.9.1.3 | <b>Description of techniques, methods and equipment</b> .....     | 52 | 2.1.9.1.3 | Beschreibung von Techniken, Methoden und Geräten.....       | 52 |
| 2.1.9.2   | <b>Energy generation and consumption (U.2)</b> .....              | 52 | 2.1.9.2   | Erzeugung und Verbrauch von Energie (U.2) .....             | 52 |
| 2.1.9.2.1 | <b>Objective</b> .....  | 52 | 2.1.9.2.1 | Zielsetzung.....  | 52 |
| 2.1.9.2.2 | <b>Field of application</b> .....                                 | 53 | 2.1.9.2.2 | Anwendungsbereich.....                                      | 53 |
| 2.1.9.2.3 | <b>Description of techniques, methods and equipment</b> .....     | 53 | 2.1.9.2.3 | Beschreibung von Techniken, Methoden und Geräten.....       | 53 |
| 2.1.9.3   | <b>Water use (U.3)</b> .....                                      | 53 | 2.1.9.3   | Wasserverbrauch (U.3) .....                                 | 53 |
| 2.1.9.3.1 | <b>Objective</b> .....  | 53 | 2.1.9.3.1 | Zielsetzung.....  | 53 |
| 2.1.9.3.2 | <b>Field of application</b> .....                                 | 54 | 2.1.9.3.2 | Anwendungsbereich.....                                      | 54 |
| 2.1.9.3.3 | <b>Process water</b> .....  | 55 | 2.1.9.3.3 | Prozesswasser .....   | 55 |
| 2.1.9.3.4 | <b>Cooling water</b> .....  | 55 | 2.1.9.3.4 | Kühlwasser.....   | 55 |
| 2.1.9.3.5 | <b>Boiler feed-water</b> .....                                    | 56 | 2.1.9.3.5 | Kesselspeisewasser .....                                    | 56 |
| 2.1.9.4   | <b>Vacuum generation (U.4)</b> .....                              | 56 | 2.1.9.4   | Vakuumerzeugung (U.4).....                                  | 56 |
| 2.1.9.4.1 | <b>Objective</b> .....  | 56 | 2.1.9.4.1 | Zielsetzung.....  | 56 |
| 2.1.9.4.2 | <b>Field of application</b> .....                                 | 56 | 2.1.9.4.2 | Anwendungsbereich.....                                      | 56 |
| 2.1.9.4.3 | <b>Description of techniques, methods and equipment</b> .....     | 56 | 2.1.9.4.3 | Beschreibung von Techniken, Methoden und Geräten.....       | 56 |
| 2.1.9.5   | <b>Refrigeration (U.5)</b> .....                                  | 57 | 2.1.9.5   | Kühlen (U.5).....   | 57 |
| 2.1.9.5.1 | <b>Objective</b> .....  | 57 | 2.1.9.5.1 | Zielsetzung.....  | 57 |
| 2.1.9.5.2 | <b>Field of application</b> .....                                 | 57 | 2.1.9.5.2 | Anwendungsbereich.....                                      | 57 |
| 2.1.9.5.3 | <b>Description of techniques, methods and equipment</b> .....     | 57 | 2.1.9.5.3 | Beschreibung von Techniken, Methoden und Geräten.....       | 57 |
| 2.1.9.6   | <b>Compressed air generation (U.6)</b> .....                      | 58 | 2.1.9.6   | Erzeugung von Druckluft (U.6) .....                         | 58 |
| 2.1.9.6.1 | <b>Objective</b> .....  | 58 | 2.1.9.6.1 | Zielsetzung.....  | 58 |
| 2.1.9.6.2 | <b>Field of application</b> .....                                 | 58 | 2.1.9.6.2 | Anwendungsbereich.....                                      | 58 |
| 2.1.9.6.3 | <b>Description of techniques</b> .....                            | 58 | 2.1.9.6.3 | Beschreibung der Techniken.....                             | 58 |
| 2.2       | <b>The application of unit operations in the FDM sector</b> ..... | 58 | 2.2       | Anwendung von Arbeitsschritten im Nahrungsmittelsektor..... | 58 |
| 2.2.1     | <b>Meat and poultry</b> .....                                     | 61 | 2.2.1     | Fleisch und Geflügel .....                                  | 61 |
| 2.2.1.1   | <b>Canned meat (beef muscle in gelatine)</b> .....                | 62 | 2.2.1.1   | Dosenfleisch (Rindfleischmuskel in Gelatine) .....          | 62 |
| 2.2.1.1.1 | <b>Thawing (A.5)</b> .....  | 62 | 2.2.1.1.1 | Auftauen (A.5).....   | 62 |
| 2.2.1.1.2 | <b>Cutting (B.1)</b> .....  | 63 | 2.2.1.1.2 | Schneiden (B.1) .....                                       | 63 |
| 2.2.1.1.3 | <b>Mixing/blending (B.2)</b> .....                                | 63 | 2.2.1.1.3 | Mischen/Verschneiden (B.2) .....                            | 63 |
| 2.2.1.1.4 | <b>Packing and filling (H.1)</b> .....                            | 63 | 2.2.1.1.4 | Verpacken und Befüllen (H.1).....                           | 63 |
| 2.2.1.1.5 | <b>Sterilisation (E.8)</b> .....                                  | 63 | 2.2.1.1.5 | Sterilisation (E.8).....                                    | 63 |
| 2.2.1.1.6 | <b>Secondary packaging (H.1)</b> .....                            | 63 | 2.2.1.1.6 | Sekundäres Verpacken (H.1) .....                            | 63 |
| 2.2.1.1.7 | <b>Refrigeration (U.5)</b> .....                                  | 63 | 2.2.1.1.7 | Kühlen (U.5).....   | 63 |
| 2.2.1.2   | <b>Cooked ham</b> .....   | 63 | 2.2.1.2   | Kochschinken.....   | 63 |
| 2.2.1.2.1 | <b>Thawing (A.5)</b> .....  | 64 | 2.2.1.2.1 | Auftauen (A.5).....   | 64 |
| 2.2.1.2.2 | <b>Cutting (B1)</b> .....   | 64 | 2.2.1.2.2 | Schneiden (B1) .....  | 64 |
| 2.2.1.2.3 | <b>Pickling (D.7)</b> .....                                       | 65 | 2.2.1.2.3 | Einlegen (D.7).....   | 65 |
| 2.2.1.2.4 | <b>Homogenisation (B.2)</b> .....                                 | 65 | 2.2.1.2.4 | Homogenisieren (B.2).....                                   | 65 |
| 2.2.1.2.5 | <b>Cooking (E.3)</b> .....  | 65 | 2.2.1.2.5 | Garen (E.3).....  | 65 |
| 2.2.1.3   | <b>Cured ham</b> .....  | 65 | 2.2.1.3   | Pökelschinken .....   | 65 |
| 2.2.1.3.1 | <b>Brining/curing (D7)</b> .....                                  | 66 | 2.2.1.3.1 | Einpökeln/Einsalzen (D7).....                               | 66 |
| 2.2.1.3.2 | <b>Ageing (D.14)</b> .....  | 67 | 2.2.1.3.2 | Reifung (D.14).....   | 67 |
| 2.2.1.3.3 | <b>Washing (A.4)</b> .....  | 67 | 2.2.1.3.3 | Waschen (A.4) .....   | 67 |
| 2.2.1.3.4 | <b>Coating (D.13)</b> .....                                       | 67 | 2.2.1.3.4 | Beschichten (D.13) .....                                    | 67 |

|           |   |     |           |  |     |
|-----------|---|-----|-----------|--|-----|
| 2.2.1.3.5 | <b>Packing (H.1)</b> .....  | 67  | 2.2.1.3.5 | <b>Verpacken (H.1)</b> .....   | 67  |
| 2.2.1.3.6 | <b>Gas flushing (H.2)</b> .....   | 67  | 2.2.1.3.6 | <b>Spülen mit Gas (H.2)</b> .....  | 67  |
| 2.2.2     | <b>Fish and shellfish</b> .....   | 67  | 2.2.2     | <b>Fisch und Muscheln</b> .....  | 67  |
| 2.2.2.1   | <b>Frozen processed fish/moulded fish products and fish fingers</b> ..... | 68  | 2.2.2.1   | <b>Tiefgekühlt verarbeitete Fisch-/Formfischprodukte und Fischstäbchen</b> ..... | 68  |
| 2.2.2.2   | <b>Canned fish/shellfish products</b> .....                               | 68  | 2.2.2.2   | <b>Dosenfisch-/Muschelprodukte</b> .....   | 68  |
| 2.2.2.3   | <b>Crustaceans</b> .....  | 69  | 2.2.2.3   | <b>Krustentiere</b> .....  | 69  |
| 2.2.2.4   | <b>Molluscs</b> .....   | 69  | 2.2.2.4   | <b>Weichtiere</b> .....  | 69  |
| 2.2.3     | <b>Fruit and vegetables</b> .....   | 69  | 2.2.3     | <b>Obst und Gemüse</b> .....   | 69  |
| 2.2.3.1   | <b>Ready meals that predominantly contain fruit and vegetables</b> .....  | 70  | 2.2.3.1   | <b>Fertiggerichte, die hauptsächlich Obst und Gemüse enthalten</b> .....         | 70  |
| 2.2.3.2   | <b>Fruit juice</b> .....  | 71  | 2.2.3.2   | <b>Obstsaft</b> .....  | 71  |
| 2.2.3.3   | <b>Heat treated fruit</b> .....   | 71  | 2.2.3.3   | <b>Wärmebehandeltes Obst</b> .....   | 71  |
| 2.2.3.4   | <b>Frozen fruit</b> .....   | 72  | 2.2.3.4   | <b>Tiefkühlobst</b> .....  | 72  |
| 2.2.3.5   | <b>Fruit preserves</b> .....  | 72  | 2.2.3.5   | <b>Obstkonserven</b> .....   | 72  |
| 2.2.3.6   | <b>Dried fruit</b> .....  | 73  | 2.2.3.6   | <b>Trockenobst</b> .....   | 73  |
| 2.2.3.7   | <b>Tomatoes</b> .....   | 73  | 2.2.3.7   | <b>Tomaten</b> .....   | 73  |
| 2.2.3.8   | <b>Potatoes</b> .....   | 73  | 2.2.3.8   | <b>Kartoffeln</b> .....  | 73  |
| 2.2.3.8.1 | <b>Potato chips</b> .....   | 74  | 2.2.3.8.1 | <b>Kartoffelchips</b> .....  | 74  |
| 2.2.3.8.2 | <b>Potato crisps</b> .....  | 74  | 2.2.3.8.2 | <b>Kartoffelcrisps</b> .....   | 74  |
| 2.2.3.9   | <b>Vegetable juice</b> .....  | 74  | 2.2.3.9   | <b>Gemüsesaft</b> .....  | 74  |
| 2.2.3.10  | <b>Heat treated and frozen vegetables</b> .....                           | 75  | 2.2.3.10  | <b>Wärmebehandeltes und tiefgekühltes Gemüse</b> .....                           | 75  |
| 2.2.3.11  | <b>Pickling of vegetables</b> .....                                       | 75  | 2.2.3.11  | <b>Eingelegtes Gemüse</b> .....  | 75  |
| 2.2.3.12  | <b>Vegetable drying</b> .....   | 75  | 2.2.3.12  | <b>Trockengemüse</b> .....   | 75  |
| 2.2.4     | <b>Vegetable oils and fats</b> .....                                      | 75  | 2.2.4     | <b>Pflanzliche Öle und Fette</b> .....   | 75  |
| 2.2.4.1   | <b>Seed oil extraction</b> .....  | 76  | 2.2.4.1   | <b>Ölsaatextraktion</b> .....  | 76  |
| 2.2.4.2   | <b>Refining of edible oils and fats</b> .....                             | 76  | 2.2.4.2   | <b>Raffinieren von Speiseölen und -fetten</b> .....                              | 76  |
| 2.2.4.3   | <b>Crystallisation of edible oils and fats</b> .....                      | 78  | 2.2.4.3   | <b>Kristallisieren von Speiseölen und -fetten</b> .....                          | 78  |
| 2.2.4.4   | <b>Further processing of edible oils and fats – margarine</b> .....       | 78  | 2.2.4.4   | <b>Weiterverarbeitung von Speiseölen und -fetten – Margarine</b> .....           | 78  |
| 2.2.4.5   | <b>Olive oil</b> .....  | 78  | 2.2.4.5   | <b>Olivenöl</b> .....  | 78  |
| 2.2.4.6   | <b>Olive-pomace oil</b> .....   | 79  | 2.2.4.6   | <b>Öl aus Oliventrester</b> .....  | 79  |
| 2.2.5     | <b>Dairy products</b> .....   | 79  | 2.2.5     | <b>Molkereiprodukte</b> .....  | 79  |
| 2.2.5.1   | <b>Milk and cream</b> .....   | 79  | 2.2.5.1   | <b>Milch und Rahm</b> .....  | 79  |
| 2.2.5.2   | <b>Condensed and powdered milk</b> .....                                  | 82  | 2.2.5.2   | <b>Kondens- und Trockenmilch</b> .....   | 82  |
| 2.2.5.3   | <b>Butter</b> .....   | 84  | 2.2.5.3   | <b>Butter</b> .....  | 84  |
| 2.2.5.4   | <b>Cheese</b> .....   | 85  | 2.2.5.4   | <b>Käse</b> .....  | 85  |
| 2.2.5.5   | <b>Yoghurt</b> .....  | 87  | 2.2.5.5   | <b>Joghurt</b> .....   | 87  |
| 2.2.5.6   | <b>Ice-cream</b> .....  | 88  | 2.2.5.6   | <b>Speiseeis</b> .....   | 88  |
| 2.2.5.7   | <b>Whey</b> .....   | 89  | 2.2.5.7   | <b>Molke</b> .....   | 89  |
| 2.2.6     | <b>Grain mill products</b> .....  | 89  | 2.2.6     | <b>Getreidemühlenprodukte</b> .....  | 89  |
| 2.2.7     | <b>Dry pasta</b> .....  | 90  | 2.2.7     | <b>Trockene Nudelwaren</b> .....   | 90  |
| 2.2.8     | <b>Starch</b> .....   | 91  | 2.2.8     | <b>Stärke</b> .....  | 91  |
| 2.2.8.1   | <b>Maize starch</b> .....   | 92  | 2.2.8.1   | <b>Maisstärke</b> .....  | 92  |
| 2.2.8.2   | <b>Wheat starch</b> .....   | 93  | 2.2.8.2   | <b>Weizenstärke</b> .....  | 93  |
| 2.2.8.3   | <b>Potato starch</b> .....  | 94  | 2.2.8.3   | <b>Kartoffelstärke</b> .....   | 94  |
| 2.2.8.4   | <b>Sweeteners</b> .....   | 96  | 2.2.8.4   | <b>Süßstoffe</b> .....   | 96  |
| 2.2.8.5   | <b>Modified (physical/chemical) starch</b> .....                          | 96  | 2.2.8.5   | <b>Modifizierte (physikalisch/chemisch) Stärke</b> .....                         | 96  |
| 2.2.9     | <b>Animal feed</b> .....  | 96  | 2.2.9     | <b>Tierfutter</b> .....  | 96  |
| 2.2.9.1   | <b>Animal feed and dry petfood</b> .....                                  | 96  | 2.2.9.1   | <b>Tierfutter und trockenes Haustierfutter</b> .....                             | 96  |
| 2.2.9.2   | <b>Moist petfood</b> .....  | 97  | 2.2.9.2   | <b>Feuchtes Haustierfutter</b> .....   | 97  |
| 2.2.9.3   | <b>Semi-moist petfood</b> .....   | 97  | 2.2.9.3   | <b>Halbfeuchtes Haustierfutter</b> .....   | 97  |
| 2.2.10    | <b>Bread</b> .....  | 97  | 2.2.10    | <b>Brot</b> .....  | 97  |
| 2.2.11    | <b>Confectionery</b> .....  | 99  | 2.2.11    | <b>Konditoreiwaren</b> .....   | 99  |
| 2.2.11.1  | <b>Biscuits</b> .....   | 99  | 2.2.11.1  | <b>Kekse</b> .....   | 99  |
| 2.2.11.2  | <b>Cakes</b> .....  | 99  | 2.2.11.2  | <b>Kuchen</b> .....  | 99  |
| 2.2.11.3  | <b>Cocoa</b> .....  | 100 | 2.2.11.3  | <b>Kakao</b> .....   | 100 |

|           |   |     |           |  |     |
|-----------|---|-----|-----------|--|-----|
| 2.2.11.4  | <b>Chocolate</b> .....  | 100 | 2.2.11.4  | Schokolade.....  | 100 |
| 2.2.11.5  | <b>Boiled sweets</b> .....                                    | 101 | 2.2.11.5  | Bonbons .....  | 101 |
| 2.2.12    | <b>Sugar</b> .....  | 101 | 2.2.12    | Zucker .....   | 101 |
| 2.2.12.1  | <b>Sugar beet extraction</b> .....                            | 101 | 2.2.12.1  | Zuckerrübenextraktion .....                                | 101 |
| 2.2.12.2  | <b>Sugar cane</b> .....                                       | 102 | 2.2.12.2  | Zuckerrohr .....   | 102 |
| 2.2.12.3  | <b>Sugar refining</b> .....                                   | 102 | 2.2.12.3  | Zuckerraffination .....                                    | 102 |
| 2.2.13    | <b>Coffee</b> .....   | 102 | 2.2.13    | Kaffee .....   | 102 |
| 2.2.13.1  | <b>Roasting coffee</b> .....                                  | 102 | 2.2.13.1  | Röstkaffee .....   | 102 |
| 2.2.13.2  | <b>Instant coffee</b> .....                                   | 103 | 2.2.13.2  | Löslicher Kaffee .....                                     | 103 |
| 2.2.13.3  | <b>Decaffeinated coffee</b> .....                             | 104 | 2.2.13.3  | Entkoffeinierter Kaffee .....                              | 104 |
| 2.2.14    | <b>Yeast</b> .....  | 105 | 2.2.14    | Hefe.....  | 105 |
| 2.2.15    | <b>Malting</b> .....  | 105 | 2.2.15    | Mälzen .....   | 105 |
| 2.2.16    | <b>Brewing</b> .....  | 106 | 2.2.16    | Brauwirtschaft.....  | 106 |
| 2.2.16.1  | <b>Mashing</b> .....  | 107 | 2.2.16.1  | Maische.....   | 107 |
| 2.2.16.2  | <b>Fermentation</b> .....                                     | 107 | 2.2.16.2  | Fermentierung.....   | 107 |
| 2.2.16.3  | <b>Maturation/conditioning</b> .....                          | 107 | 2.2.16.3  | Reifen/Konditionieren.....                                 | 107 |
| 2.2.17    | <b>Distilling</b> .....                                       | 108 | 2.2.17    | Destillation.....  | 108 |
| 2.2.17.1  | <b>Scotch whisky</b> .....                                    | 108 | 2.2.17.1  | Schottischer Whisky .....                                  | 108 |
| 2.2.17.2  | <b>Cognac</b> .....   | 108 | 2.2.17.2  | Cognac .....   | 108 |
| 2.2.18    | <b>Wine</b> .....   | 109 | 2.2.18    | Wein.....  | 109 |
| 2.2.18.1  | <b>Reception</b> .....  | 109 | 2.2.18.1  | Annahme.....   | 109 |
| 2.2.18.2  |   |     | 2.2.18.2  | Zerquetschen und Entstielen von<br>Trauben .....           | 109 |
| 2.2.18.3  | <b>Grape crushing and destemming</b> .....                    | 109 | 2.2.18.3  | Auspressen .....   | 109 |
| 2.2.18.4  | <b>Pressing</b> .....   | 109 | 2.2.18.4  | Klären .....   | 109 |
| 2.2.18.5  | <b>Fining</b> .....   | 109 | 2.2.18.5  | Fermentierung.....   | 109 |
| 2.2.18.6  | <b>Fermentation</b> .....                                     | 109 | 2.2.18.6  | Reifung .....  | 109 |
| 2.2.18.7  | <b>Ageing</b> .....   | 109 | 2.2.18.7  | Kältestabilisation .....                                   | 110 |
| 2.2.18.8  | <b>Cold stabilisation</b> .....                               | 110 | 2.2.18.8  | Abfüllen in Flaschen .....                                 | 110 |
| 2.2.18.9  | <b>Bottling</b> .....   | 110 | 2.2.19    | Alkoholfreie Getränke .....                                | 110 |
| 2.2.19    | <b>Soft drinks</b> .....                                      | 110 | 2.2.20    | Zitronensäure .....  | 110 |
| 2.2.20    | <b>Citric acid</b> .....                                      | 110 | 3         | <b>DERZEITIGE VERBRAUCHS-<br/>UND EMISSIONSPEGEL</b> ..... | 113 |
| 3         | <b>CURRENT CONSUMPTION<br/>AND EMISSION LEVELS</b> .....      | 113 | 3.1       | Allgemeine Angaben zu Verbrauch<br>und Emissionen.....     | 115 |
| 3.1       | <b>General consumption and<br/>emission information</b> ..... | 115 | 3.1.1     | Wasser.....  | 115 |
| 3.1.1     | <b>Water</b> .....  | 115 | 3.1.1.1   | Wasserverbrauch.....                                       | 115 |
| 3.1.1.1   | <b>Water consumption</b> .....                                | 115 | 3.1.1.2   | Abwasser.....  | 116 |
| 3.1.1.2   | <b>Waste water</b> .....                                      | 116 | 3.1.1.2.1 | Abwassermenge .....  | 116 |
| 3.1.1.2.1 | <b>Quantity of waste water</b> .....                          | 116 | 3.1.1.2.2 | Abwasserzusammensetzung.....                               | 117 |
| 3.1.1.2.2 | <b>Composition of waste water</b> .....                       | 117 | 3.1.2     | Luftemissionen.....  | 118 |
| 3.1.2     | <b>Air emissions</b> .....                                    | 118 | 3.1.2.1   | Geruchsbildung .....                                       | 119 |
| 3.1.2.1   | <b>Odour</b> .....  | 119 | 3.1.3     | Materialverluste .....                                     | 119 |
| 3.1.3     | <b>Loss of materials</b> .....                                | 119 | 3.1.3.1   | Überschreiten der Gewichts-<br>/Volumenvorgaben.....       | 119 |
| 3.1.3.1   | <b>Exceed weight/volume<br/>specification</b> .....           | 119 | 3.1.3.2   | Verschütten .....  | 119 |
| 3.1.3.2   | <b>Spillage</b> .....   | 119 | 3.1.3.3   | Aus-/Überlaufen.....                                       | 119 |
| 3.1.3.3   | <b>Leakage/overflow</b> .....                                 | 119 | 3.1.3.4   | Defekte/zurückgegebene Produkte .....                      | 120 |
| 3.1.3.4   | <b>Product defects/returned product</b> ....                  | 120 | 3.1.3.5   | Inhärente Verluste.....                                    | 120 |
| 3.1.3.5   | <b>Inherent loss</b> .....                                    | 120 | 3.1.3.6   | Zurückgehaltene Stoffe.....                                | 120 |
| 3.1.3.6   | <b>Retained material</b> .....                                | 120 | 3.1.3.7   | Wärmebedingte Abfälle .....                                | 120 |
| 3.1.3.7   | <b>Heat deposited waste</b> .....                             | 120 | 3.1.4     | Energie .....  | 120 |
| 3.1.4     | <b>Energy</b> .....   | 120 | 3.2       | Verbrauch und Emissionen bei<br>Arbeitsgängen .....        | 121 |
| 3.2       | <b>Consumption and emissions in<br/>unit operations</b> ..... | 121 | 3.2.1     | Materialhandhabung und -lagerung<br>(A.1).....             | 123 |
| 3.2.1     | <b>Materials handling and storage<br/>(A.1)</b> .....         | 123 | 3.2.1.1   | Wasser.....  | 123 |
| 3.2.1.1   | <b>Water</b> .....  | 123 | 3.2.1.2   | Luftemissionen.....  | 123 |
| 3.2.1.2   | <b>Air emissions</b> .....                                    | 123 | 3.2.1.3   | Abgegebene Feststoffe.....                                 | 124 |
| 3.2.1.3   | <b>Solid output</b> .....                                     | 124 | 3.2.1.4   | Energie .....  | 124 |
| 3.2.1.4   | <b>Energy</b> .....   | 124 | 3.2.1.5   | Lärm.....  | 124 |
| 3.2.1.5   | <b>Noise</b> .....  | 124 | 3.2.1.6   | Unbeabsichtigte Freisetzung.....                           | 124 |
| 3.2.1.6   | <b>Accidental release</b> .....                               | 124 |           |  |     |

|          |  |     |          |   |     |
|----------|--|-----|----------|---|-----|
| 3.2.2    | <b>Sorting/screening, grading, dehulling, destemming/destalking and trimming (A.2)</b> ..... | 124 | 3.2.2    | Sortieren/Sieben, Klassifizieren, Enthülsen, Entfernen von Stielen/Stämmen und Zurechtschneiden (A.2) ..... | 124 |
| 3.2.2.1  | <b>Water</b> .....   | 124 | 3.2.2.1  | Wasser .....  | 124 |
| 3.2.2.2  | <b>Air emissions</b> .....   | 124 | 3.2.2.2  | Luftemissionen .....  | 124 |
| 3.2.2.3  | <b>Solid output</b> .....  | 124 | 3.2.2.3  | Abgegebene Feststoffe .....   | 124 |
| 3.2.2.4  | <b>Energy</b> .....  | 124 | 3.2.2.4  | Energie.....  | 124 |
| 3.2.3    | <b>Peeling (A.3)</b> .....   | 125 | 3.2.3    | Schälen (A.3).....  | 125 |
| 3.2.3.1  | <b>Water</b> .....   | 125 | 3.2.3.1  | Wasser .....  | 125 |
| 3.2.3.2  | <b>Air emissions</b> .....   | 125 | 3.2.3.2  | Luftemissionen .....  | 125 |
| 3.2.3.3  | <b>Solid output</b> .....  | 125 | 3.2.3.3  | Abgegebene Feststoffe .....   | 125 |
| 3.2.3.4  | <b>Energy</b> .....  | 125 | 3.2.3.4  | Energie.....  | 125 |
| 3.2.3.5  | <b>Noise</b> .....   | 125 | 3.2.3.5  | Lärm .....  | 125 |
| 3.2.4    | <b>Washing (A.4) and thawing (A.5)</b> ....  | 125 | 3.2.4    | Waschen (A.4) und Auftauen (A.5)....  | 125 |
| 3.2.4.1  | <b>Water</b> .....   | 125 | 3.2.4.1  | Wasser .....  | 125 |
| 3.2.4.2  | <b>Solid output</b> .....  | 125 | 3.2.4.2  | Abgegebene Feststoffe .....   | 125 |
| 3.2.4.3  | <b>Energy</b> .....  | 126 | 3.2.4.3  | Energie.....  | 126 |
| 3.2.5    | <b>Cutting, slicing, chopping, mincing, pulping and pressing (B.1)</b> .....                 | 126 | 3.2.5    | Zerteilen, Schneiden, Zerhacken, Mahlen, Quetschen und Pressen (B.1).....                                   | 126 |
| 3.2.5.1  | <b>Water</b> .....   | 126 | 3.2.5.1  | Wasser .....  | 126 |
| 3.2.5.2  | <b>Solid output</b> .....  | 126 | 3.2.5.2  | Abgegebene Feststoffe .....   | 126 |
| 3.2.5.3  | <b>Energy</b> .....  | 126 | 3.2.5.3  | Energie.....  | 126 |
| 3.2.5.4  | <b>Noise</b> .....   | 126 | 3.2.5.4  | Lärm .....  | 126 |
| 3.2.6    | <b>Mixing/blending, homogenisation and conching (B.2)</b> .....                              | 126 | 3.2.6    | Mischen/Verschneiden, Homogenisieren und Conchieren (B.2).....  | 126 |
| 3.2.6.1  | <b>Water</b> .....   | 126 | 3.2.6.1  | Wasser .....  | 126 |
| 3.2.6.2  | <b>Air emissions</b> .....   | 126 | 3.2.6.2  | Luftemissionen .....  | 126 |
| 3.2.6.3  | <b>Solid output</b> .....  | 126 | 3.2.6.3  | Abgegebene Feststoffe .....   | 126 |
| 3.2.6.4  | <b>Energy</b> .....  | 127 | 3.2.6.4  | Energie.....  | 127 |
| 3.2.6.5  | <b>Noise</b> .....   | 127 | 3.2.6.5  | Lärm .....  | 127 |
| 3.2.7    | <b>Grinding/milling and crushing (B.3)</b> .....   | 127 | 3.2.7    | Schroten/Mahlen und Zerstoßen (B.3).....  | 127 |
| 3.2.7.1  | <b>Water</b> .....   | 127 | 3.2.7.1  | Wasser .....  | 127 |
| 3.2.7.2  | <b>Air emissions</b> .....   | 127 | 3.2.7.2  | Luftemissionen .....  | 127 |
| 3.2.7.3  | <b>Solid output</b> .....  | 127 | 3.2.7.3  | Abgegebene Feststoffe .....   | 127 |
| 3.2.7.4  | <b>Energy</b> .....  | 127 | 3.2.7.4  | Energie.....  | 127 |
| 3.2.7.5  | <b>Noise</b> .....   | 127 | 3.2.7.5  | Lärm .....  | 127 |
| 3.2.8    | <b>Forming/moulding and extruding (B.4)</b> .....  | 127 | 3.2.8    | Formen und Extrudieren (B.4).....   | 127 |
| 3.2.8.1  | <b>Water</b> .....   | 127 | 3.2.8.1  | Wasser .....  | 127 |
| 3.2.8.2  | <b>Air emissions</b> .....   | 127 | 3.2.8.2  | Luftemissionen .....  | 127 |
| 3.2.8.3  | <b>Solid output</b> .....  | 127 | 3.2.8.3  | Abgegebene Feststoffe .....   | 127 |
| 3.2.8.4  | <b>Energy</b> .....  | 127 | 3.2.8.4  | Energie.....  | 127 |
| 3.2.9    | <b>Extraction (C.1)</b> .....  | 128 | 3.2.9    | Extraktion (C.1).....   | 128 |
| 3.2.9.1  | <b>Water</b> .....   | 128 | 3.2.9.1  | Wasser .....  | 128 |
| 3.2.9.2  | <b>Air emissions</b> .....   | 128 | 3.2.9.2  | Luftemissionen .....  | 128 |
| 3.2.9.3  | <b>Solid output</b> .....  | 128 | 3.2.9.3  | Abgegebene Feststoffe .....   | 128 |
| 3.2.9.4  | <b>Energy</b> .....  | 128 | 3.2.9.4  | Energie.....  | 128 |
| 3.2.9.5  | <b>Noise</b> .....   | 128 | 3.2.9.5  | Lärm .....  | 128 |
| 3.2.10   | <b>Deionisation (C.2)</b> .....  | 128 | 3.2.10   | Deionisation (C.2) .....  | 128 |
| 3.2.10.1 | <b>Water</b> .....   | 128 | 3.2.10.1 | Wasser .....  | 128 |
| 3.2.10.2 | <b>Solid output</b> .....  | 129 | 3.2.10.2 | Abgegebene Feststoffe .....   | 129 |
| 3.2.11   | <b>Fining (C.3)</b> .....  | 129 | 3.2.11   | Klären (C.3).....   | 129 |
| 3.2.11.1 | <b>Water</b> .....   | 129 | 3.2.11.1 | Wasser .....  | 129 |
| 3.2.11.2 | <b>Solid output</b> .....  | 129 | 3.2.11.2 | Abgegebene Feststoffe .....   | 129 |
| 3.2.12   | <b>Centrifugation and sedimentation (C.4)</b> .....  | 129 | 3.2.12   | Zentrifugieren und Sedimentieren (C.4).....   | 129 |
| 3.2.12.1 | <b>Water</b> .....   | 129 | 3.2.12.1 | Wasser .....  | 129 |
| 3.2.12.2 | <b>Solid output</b> .....  | 129 | 3.2.12.2 | Abgegebene Feststoffe .....   | 129 |
| 3.2.12.3 | <b>Energy</b> .....  | 129 | 3.2.12.3 | Energie.....  | 129 |

|          |   |     |          |   |     |
|----------|---|-----|----------|---|-----|
| 3.2.12.4 | Noise .....   | 129 | 3.2.12.4 | Lärm.....   | 129 |
| 3.2.13   | Filtration (C.5).....                                       | 129 | 3.2.13   | Filtrieren (C.5) .....  | 129 |
| 3.2.13.1 | Water .....   | 129 | 3.2.13.1 | Wasser.....   | 129 |
| 3.2.13.2 | Air emissions .....   | 129 | 3.2.13.2 | Luftemissionen.....   | 129 |
| 3.2.13.3 | Solid output.....   | 130 | 3.2.13.3 | Abgegebene Feststoffe.....                                      | 130 |
| 3.2.13.4 | Energy .....  | 130 | 3.2.13.4 | Energie .....   | 130 |
| 3.2.14   | Membrane separation (C.6).....                              | 130 | 3.2.14   | Membrantrennverfahren (C.6) .....                               | 130 |
| 3.2.14.1 | Water .....   | 130 | 3.2.14.1 | Wasser.....   | 130 |
| 3.2.14.2 | Energy .....  | 130 | 3.2.14.2 | Energie .....   | 130 |
| 3.2.15   | Crystallisation (C.7) .....                                 | 130 | 3.2.15   | Kristallisation (C.7).....                                      | 130 |
| 3.2.15.1 | Water .....   | 130 | 3.2.15.1 | Wasser.....   | 130 |
| 3.2.15.2 | Solid output.....   | 130 | 3.2.15.2 | Abgegebene Feststoffe.....                                      | 130 |
| 3.2.15.3 | Energy .....  | 130 | 3.2.15.3 | Energie .....   | 130 |
| 3.2.16   | Removal of free fatty acids by<br>neutralisation (C.8)..... | 130 | 3.2.16   | Beseitigen freier Fettsäuren durch<br>Neutralisation (C.8)..... | 130 |
| 3.2.16.1 | Water .....   | 130 | 3.2.16.1 | Wasser.....   | 130 |
| 3.2.16.2 | Air emissions .....   | 130 | 3.2.16.2 | Luftemissionen.....   | 130 |
| 3.2.16.3 | Solid output.....   | 131 | 3.2.16.3 | Abgegebene Feststoffe.....                                      | 131 |
| 3.2.16.4 | Energy .....  | 131 | 3.2.16.4 | Energie .....   | 131 |
| 3.2.17   | Bleaching (C.9).....  | 131 | 3.2.17   | Bleichen (C.9).....   | 131 |
| 3.2.17.1 | Air emissions .....   | 131 | 3.2.17.1 | Luftemissionen.....   | 131 |
| 3.2.17.2 | Solid output.....   | 131 | 3.2.17.2 | Abgegebene Feststoffe.....                                      | 131 |
| 3.2.17.3 | Energy .....  | 131 | 3.2.17.3 | Energie .....   | 131 |
| 3.2.18   | Deodorisation by steam stripping<br>(C.10) .....            | 131 | 3.2.18   | Desodorieren durch Dampf-<br>Stripping (C.10) .....             | 131 |
| 3.2.18.1 | Water .....   | 131 | 3.2.18.1 | Wasser.....   | 131 |
| 3.2.18.2 | Air emissions .....   | 131 | 3.2.18.2 | Luftemissionen.....   | 131 |
| 3.2.18.3 | Solid output.....   | 131 | 3.2.18.3 | Abgegebene Feststoffe.....                                      | 131 |
| 3.2.18.4 | Energy .....  | 131 | 3.2.18.4 | Energie .....   | 131 |
| 3.2.18.5 | Noise .....   | 132 | 3.2.18.5 | Lärm.....   | 132 |
| 3.2.19   | Decolourisation (C.11).....                                 | 132 | 3.2.19   | Entfärben (C.11) .....  | 132 |
| 3.2.19.1 | Water .....   | 132 | 3.2.19.1 | Wasser.....   | 132 |
| 3.2.19.2 | Solid output.....   | 132 | 3.2.19.2 | Abgegebene Feststoffe.....                                      | 132 |
| 3.2.19.3 | Energy .....  | 132 | 3.2.19.3 | Energie .....   | 132 |
| 3.2.20   | Distillation (C.12).....                                    | 132 | 3.2.20   | Destillation (C12) .....  | 132 |
| 3.2.20.1 | Water .....   | 132 | 3.2.20.1 | Wasser.....   | 132 |
| 3.2.20.2 | Air emissions .....   | 132 | 3.2.20.2 | Luftemissionen.....   | 132 |
| 3.2.20.3 | Solid output.....   | 132 | 3.2.20.3 | Abgegebene Feststoffe.....                                      | 132 |
| 3.2.20.4 | Energy .....  | 132 | 3.2.20.4 | Energie .....   | 132 |
| 3.2.20.5 | Noise .....   | 133 | 3.2.20.5 | Lärm.....   | 133 |
| 3.2.21   | Soaking (D.1).....  | 133 | 3.2.21   | Einweichen (D.1) .....  | 133 |
| 3.2.21.1 | Water .....   | 133 | 3.2.21.1 | Wasser.....   | 133 |
| 3.2.21.2 | Solid output .....  | 133 | 3.2.21.2 | Abgegebene Feststoffe.....                                      | 133 |
| 3.2.22   | Dissolving (D.2).....                                       | 133 | 3.2.22   | Auflösen (D.2) .....  | 133 |
| 3.2.22.1 | Water .....   | 133 | 3.2.22.1 | Wasser.....   | 133 |
| 3.2.22.2 | Air emissions .....   | 133 | 3.2.22.2 | Luftemissionen.....   | 133 |
| 3.2.22.3 | Energy .....  | 133 | 3.2.22.3 | Energie .....   | 133 |
| 3.2.23   | Solubilisation/alkalising (D.3).....                        | 133 | 3.2.23   | Solubilisation/Alkalisieren (D.3) .....                         | 133 |
| 3.2.23.1 | Water .....   | 133 | 3.2.23.1 | Wasser.....   | 133 |
| 3.2.23.2 | Air emissions .....   | 133 | 3.2.23.2 | Luftemissionen.....   | 133 |
| 3.2.23.3 | Energy .....  | 133 | 3.2.23.3 | Energie .....   | 133 |
| 3.2.24   | Fermentation (D.4) .....                                    | 134 | 3.2.24   | Fermentation (D.4).....   | 134 |
| 3.2.24.1 | Water.....  | 134 | 3.2.24.1 | Wasser.....   | 134 |
| 3.2.24.2 | Air emissions.....  | 134 | 3.2.24.2 | Luftemissionen.....   | 134 |
| 3.2.24.3 | Solid output.....   | 134 | 3.2.24.3 | Abgegebene Feststoffe.....                                      | 134 |
| 3.2.24.4 | Energy .....  | 134 | 3.2.24.4 | Energie .....   | 134 |
| 3.2.25   | Coagulation (D.5).....                                      | 134 | 3.2.25   | Koagulation (D.5) .....   | 134 |
| 3.2.25.1 | Water .....   | 134 | 3.2.25.1 | Wasser.....   | 134 |
| 3.2.25.2 | Energy .....  | 134 | 3.2.25.2 | Energie .....   | 134 |
| 3.2.26   | Germination (D.6) .....                                     | 134 | 3.2.26   | Keimung (D.6) .....   | 134 |
| 3.2.26.1 | Water .....   | 134 | 3.2.26.1 | Wasser.....   | 134 |
| 3.2.26.2 | Air emissions .....   | 134 | 3.2.26.2 | Luftemissionen.....   | 134 |
| 3.2.26.3 | Energy .....  | 134 | 3.2.26.3 | Energie .....   | 134 |

|          |  |     |          |  |     |
|----------|--|-----|----------|--|-----|
| 3.2.27   | <b>Brining/curing and pickling (D.7)....</b>                                   | 135 | 3.2.27   | <b>Einpökeln/Einsalzen und Einlegen (D.7) .....</b>                              | 135 |
| 3.2.27.1 | <b>Water.....</b>  | 135 | 3.2.27.1 | <b>Wasser .....</b>  | 135 |
| 3.2.28   | <b>Smoking (D.8).....</b>  | 135 | 3.2.28   | <b>Räuchern (D.8) .....</b>  | 135 |
| 3.2.28.1 | <b>Water.....</b>  | 135 | 3.2.28.1 | <b>Wasser .....</b>  | 135 |
| 3.2.28.2 | <b>Air emissions.....</b>  | 135 | 3.2.28.2 | <b>Luftemissionen .....</b>  | 135 |
| 3.2.28.3 | <b>Solid output.....</b>   | 135 | 3.2.28.3 | <b>Abgegebene Feststoffe .....</b>   | 135 |
| 3.2.28.4 | <b>Energy .....</b>  | 135 | 3.2.28.4 | <b>Energie.....</b>  | 135 |
| 3.2.29   | <b>Hardening (D.9).....</b>  | 135 | 3.2.29   | <b>Härten (D.9).....</b>   | 135 |
| 3.2.29.1 | <b>Water.....</b>  | 135 | 3.2.29.1 | <b>Wasser .....</b>  | 135 |
| 3.2.29.2 | <b>Air emissions.....</b>  | 135 | 3.2.29.2 | <b>Luftemissionen .....</b>  | 135 |
| 3.2.29.3 | <b>Solid output.....</b>   | 135 | 3.2.29.3 | <b>Abgegebene Feststoffe .....</b>   | 135 |
| 3.2.29.4 | <b>Energy .....</b>  | 136 | 3.2.29.4 | <b>Energie.....</b>  | 136 |
| 3.2.29.5 | <b>Noise .....</b>   | 136 | 3.2.29.5 | <b>Lärm .....</b>  | 136 |
| 3.2.30   | <b>Sulphitation (D.10).....</b>  | 136 | 3.2.30   | <b>Sulfitieren (D.10).....</b>   | 136 |
| 3.2.30.1 | <b>Air emissions.....</b>  | 136 | 3.2.30.1 | <b>Luftemissionen .....</b>  | 136 |
| 3.2.31   | <b>Carbonatation (D.11).....</b>   | 136 | 3.2.31   | <b>Carbonatation (D.11).....</b>   | 136 |
| 3.2.31.1 | <b>Air emissions.....</b>  | 136 | 3.2.31.1 | <b>Luftemissionen .....</b>  | 136 |
| 3.2.31.2 | <b>Solid output.....</b>   | 136 | 3.2.31.2 | <b>Abgegebene Feststoffe .....</b>   | 136 |
| 3.2.31.3 | <b>Noise .....</b>   | 136 | 3.2.31.3 | <b>Lärm .....</b>  | 136 |
| 3.2.32   | <b>Carbonation (D.12) .....</b>  | 136 | 3.2.32   | <b>Versetzen mit Kohlensäure (D.12) .....</b>                                    | 136 |
| 3.2.32.1 | <b>Air emissons .....</b>  | 136 | 3.2.32.1 | <b>Luftemissionen .....</b>  | 136 |
| 3.2.32.2 | <b>Energy .....</b>  | 136 | 3.2.32.2 | <b>Energie.....</b>  | 136 |
| 3.2.33   | <b>Coating/spraying/enrobing/agglo-<br/>meration/encapsulation (D.13).....</b> | 136 | 3.2.33   | <b>Beschichten/Besprühen/<br/>Einkleiden/Sintern/Einkapseln<br/>(D.13) .....</b> | 136 |
| 3.2.33.1 | <b>Water.....</b>  | 136 | 3.2.33.1 | <b>Wasser .....</b>  | 136 |
| 3.2.33.2 | <b>Air emissions.....</b>  | 137 | 3.2.33.2 | <b>Luftemissionen .....</b>  | 137 |
| 3.2.33.3 | <b>Solid output.....</b>   | 137 | 3.2.33.3 | <b>Abgegebene Feststoffe .....</b>   | 137 |
| 3.2.34   | <b>Ageing (D.14).....</b>  | 137 | 3.2.34   | <b>Reifung (D.14).....</b>   | 137 |
| 3.2.34.1 | <b>Water.....</b>  | 137 | 3.2.34.1 | <b>Wasser .....</b>  | 137 |
| 3.2.34.2 | <b>Air emissions.....</b>  | 137 | 3.2.34.2 | <b>Luftemissionen .....</b>  | 137 |
| 3.2.34.3 | <b>Solid output.....</b>   | 137 | 3.2.34.3 | <b>Abgegebene Feststoffe .....</b>   | 137 |
| 3.2.35   | <b>Melting (E.1).....</b>  | 137 | 3.2.35   | <b>Schmelzen (E.1) .....</b>   | 137 |
| 3.2.35.1 | <b>Water.....</b>  | 137 | 3.2.35.1 | <b>Wasser .....</b>  | 137 |
| 3.2.35.2 | <b>Air emissions.....</b>  | 137 | 3.2.35.2 | <b>Luftemissionen .....</b>  | 137 |
| 3.2.35.3 | <b>Solid output.....</b>   | 137 | 3.2.35.3 | <b>Abgegebene Feststoffe .....</b>   | 137 |
| 3.2.35.4 | <b>Energy .....</b>  | 137 | 3.2.35.4 | <b>Energie.....</b>  | 137 |
| 3.2.36   | <b>Blanching (E.2).....</b>  | 137 | 3.2.36   | <b>Blanchieren (E.2).....</b>  | 137 |
| 3.2.36.1 | <b>Water.....</b>  | 137 | 3.2.36.1 | <b>Wasser .....</b>  | 137 |
| 3.2.36.2 | <b>Air emissions.....</b>  | 138 | 3.2.36.2 | <b>Luftemissionen .....</b>  | 138 |
| 3.2.36.3 | <b>Solid output.....</b>   | 138 | 3.2.36.3 | <b>Abgegebene Feststoffe .....</b>   | 138 |
| 3.2.36.4 | <b>Energy .....</b>  | 138 | 3.2.36.4 | <b>Energie.....</b>  | 138 |
| 3.2.37   | <b>Cooking and boiling (E.3).....</b>  | 138 | 3.2.37   | <b>Garen und Kochen (E.3).....</b>   | 138 |
| 3.2.37.1 | <b>Water.....</b>  | 138 | 3.2.37.1 | <b>Wasser .....</b>  | 138 |
| 3.2.37.2 | <b>Air emissions.....</b>  | 138 | 3.2.37.2 | <b>Luftemissionen .....</b>  | 138 |
| 3.2.37.3 | <b>Solid output.....</b>   | 138 | 3.2.37.3 | <b>Abgegebene Feststoffe .....</b>   | 138 |
| 3.2.37.4 | <b>Energy .....</b>  | 138 | 3.2.37.4 | <b>Energie.....</b>  | 138 |
| 3.2.38   | <b>Baking (E.4).....</b>   | 138 | 3.2.38   | <b>Backen (E.4).....</b>   | 138 |
| 3.2.38.1 | <b>Water.....</b>  | 138 | 3.2.38.1 | <b>Wasser .....</b>  | 138 |
| 3.2.38.2 | <b>Air emissions.....</b>  | 138 | 3.2.38.2 | <b>Luftemissionen .....</b>  | 138 |
| 3.2.38.3 | <b>Solid output.....</b>   | 138 | 3.2.38.3 | <b>Abgegebene Feststoffe .....</b>   | 138 |
| 3.2.38.4 | <b>Energy .....</b>  | 139 | 3.2.38.4 | <b>Energie.....</b>  | 139 |
| 3.2.39   | <b>Roasting (E.5).....</b>   | 139 | 3.2.39   | <b>Rösten (E.5).....</b>   | 139 |
| 3.2.39.1 | <b>Water.....</b>  | 139 | 3.2.39.1 | <b>Wasser .....</b>  | 139 |
| 3.2.39.2 | <b>Air emissions.....</b>  | 139 | 3.2.39.2 | <b>Luftemissionen .....</b>  | 139 |
| 3.2.39.3 | <b>Solid output.....</b>   | 139 | 3.2.39.3 | <b>Abgegebene Feststoffe .....</b>   | 139 |
| 3.2.39.4 | <b>Energy .....</b>  | 139 | 3.2.39.4 | <b>Energie.....</b>  | 139 |
| 3.2.40   | <b>Frying (E.6).....</b>   | 139 | 3.2.40   | <b>Braten/Frittieren (E.6).....</b>  | 139 |
| 3.2.40.1 | <b>Water.....</b>  | 139 | 3.2.40.1 | <b>Wasser .....</b>  | 139 |
| 3.2.40.2 | <b>Air emissions.....</b>  | 139 | 3.2.40.2 | <b>Luftemissionen .....</b>  | 139 |
| 3.2.40.3 | <b>Solid output.....</b>   | 140 | 3.2.40.3 | <b>Abgegebene Feststoffe .....</b>   | 140 |
| 3.2.40.4 | <b>Energy .....</b>  | 140 | 3.2.40.4 | <b>Energie.....</b>  | 140 |

|          |   |     |          |   |     |
|----------|---|-----|----------|---|-----|
| 3.2.41   | <b>Tempering (E.7)</b> .....                                | 140 | 3.2.41   | Temperieren (E.7).....  | 140 |
| 3.2.41.1 | <b>Water</b> .....  | 140 | 3.2.41.1 | Wasser.....   | 140 |
| 3.2.41.2 | <b>Energy</b> .....   | 140 | 3.2.41.2 | Energie.....  | 140 |
| 3.2.42   | <b>Pasteurisation, sterilisation and UHT (E.8)</b> .....    | 140 | 3.2.42   | Pasteurisieren, Sterilisieren und Ultrahoherhitzen (E.8)..... | 140 |
| 3.2.42.1 | <b>Water</b> .....  | 140 | 3.2.42.1 | Wasser.....   | 140 |
| 3.2.42.2 | <b>Energy</b> .....   | 140 | 3.2.42.2 | Energie.....  | 140 |
| 3.2.43   | <b>Evaporation (liquid to liquid) (F.1)</b> .....           | 140 | 3.2.43   | Verdampfung (flüssig nach flüssig) (F.1) .....                | 140 |
| 3.2.43.1 | <b>Water</b> .....  | 140 | 3.2.43.1 | Wasser.....   | 140 |
| 3.2.43.2 | <b>Air emissions</b> .....                                  | 140 | 3.2.43.2 | Luftemissionen.....   | 140 |
| 3.2.43.3 | <b>Energy</b> .....   | 141 | 3.2.43.3 | Energie.....  | 141 |
| 3.2.43.4 | <b>Noise</b> .....  | 141 | 3.2.43.4 | Lärm.....   | 141 |
| 3.2.44   | <b>Drying (liquid to solid) (F.2)</b> .....                 | 141 | 3.2.44   | Trocknung (flüssig nach trocken) (F.2) .....                  | 141 |
| 3.2.44.1 | <b>Water</b> .....  | 141 | 3.2.44.1 | Wasser.....   | 141 |
| 3.2.44.2 | <b>Air emissions</b> .....                                  | 141 | 3.2.44.2 | Luftemissionen.....   | 141 |
| 3.2.44.3 | <b>Solid output</b> .....                                   | 141 | 3.2.44.3 | Abgegebene Feststoffe.....                                    | 141 |
| 3.2.44.4 | <b>Energy</b> .....   | 141 | 3.2.44.4 | Energie.....  | 141 |
| 3.2.44.5 | <b>Noise</b> .....  | 141 | 3.2.44.5 | Lärm.....   | 141 |
| 3.2.45   | <b>Dehydration (solid to solid) (F.3)</b> .....             | 142 | 3.2.45   | Dehydration (fest nach fest) (F.3) .....                      | 142 |
| 3.2.45.1 | <b>Water</b> .....  | 142 | 3.2.45.1 | Wasser.....   | 142 |
| 3.2.45.2 | <b>Air emissions</b> .....                                  | 142 | 3.2.45.2 | Luftemissionen.....   | 142 |
| 3.2.45.3 | <b>Solid output</b> .....                                   | 142 | 3.2.45.3 | Abgegebene Feststoffe.....                                    | 142 |
| 3.2.45.4 | <b>Energy</b> .....   | 142 | 3.2.45.4 | Energie.....  | 142 |
| 3.2.45.5 | <b>Noise</b> .....  | 142 | 3.2.45.5 | Lärm.....   | 142 |
| 3.2.46   | <b>Cooling, chilling and cold stabilisation (G.1)</b> ..... | 142 | 3.2.46   | Kühlen, Abkühlen und Kältestabilisation (G.1).....            | 142 |
| 3.2.46.1 | <b>Water</b> .....  | 142 | 3.2.46.1 | Wasser.....   | 142 |
| 3.2.46.2 | <b>Air emissions</b> .....                                  | 142 | 3.2.46.2 | Luftemissionen.....   | 142 |
| 3.2.46.3 | <b>Energy</b> .....   | 142 | 3.2.46.3 | Energie.....  | 142 |
| 3.2.46.4 | <b>Noise</b> .....  | 143 | 3.2.46.4 | Lärm.....   | 143 |
| 3.2.47   | <b>Freezing (G.2)</b> .....                                 | 143 | 3.2.47   | Tiefkühlen (G.2) .....  | 143 |
| 3.2.47.1 | <b>Water</b> .....  | 143 | 3.2.47.1 | Wasser.....   | 143 |
| 3.2.47.2 | <b>Air emissions</b> .....                                  | 143 | 3.2.47.2 | Luftemissionen.....   | 143 |
| 3.2.47.3 | <b>Energy</b> .....   | 143 | 3.2.47.3 | Energie.....  | 143 |
| 3.2.47.4 | <b>Noise</b> .....  | 143 | 3.2.47.4 | Lärm.....   | 143 |
| 3.2.48   | <b>Freeze-drying/lyophilisation (G.3) ...</b>               | 144 | 3.2.48   | Gefriertrocknen/Lyophilisation (G.3) ..                       | 144 |
| 3.2.48.1 | <b>Water</b> .....  | 144 | 3.2.48.1 | Wasser.....   | 144 |
| 3.2.48.2 | <b>Energy</b> .....   | 144 | 3.2.48.2 | Energie.....  | 144 |
| 3.2.49   | <b>Packing and filling (H.1)</b> .....                      | 144 | 3.2.49   | Verpacken und Befüllen (H.1).....                             | 144 |
| 3.2.49.1 | <b>Water</b> .....  | 144 | 3.2.49.1 | Wasser.....   | 144 |
| 3.2.49.2 | <b>Air emissions</b> .....                                  | 144 | 3.2.49.2 | Luftemissionen.....   | 144 |
| 3.2.49.3 | <b>Solid output</b> .....                                   | 144 | 3.2.49.3 | Abgegebene Feststoffe.....                                    | 144 |
| 3.2.49.4 | <b>Energy</b> .....   | 144 | 3.2.49.4 | Energie.....  | 144 |
| 3.2.49.5 | <b>Noise</b> .....  | 144 | 3.2.49.5 | Lärm.....   | 144 |
| 3.2.50   | <b>Gas flushing and storage under gas (H.2)</b> .....       | 144 | 3.2.50   | Gasspülung und Lagerung unter Gas (H.2).....                  | 144 |
| 3.2.50.1 | <b>Air emissions</b> .....                                  | 144 | 3.2.50.1 | Luftemissionen.....   | 144 |
| 3.2.51   | <b>Cleaning and disinfection (U.1)</b> .....                | 145 | 3.2.51   | Reinigung und Desinfektion (U.1).....                         | 145 |
| 3.2.51.1 | <b>Water</b> .....  | 145 | 3.2.51.1 | Wasser.....   | 145 |
| 3.2.51.2 | <b>Solid output</b> .....                                   | 145 | 3.2.51.2 | Abgegebene Feststoffe.....                                    | 145 |
| 3.2.51.3 | <b>Energy</b> .....   | 145 | 3.2.51.3 | Energie.....  | 145 |
| 3.2.52   | <b>Energy generation and consumption (U.2)</b> .....        | 145 | 3.2.52   | Erzeugung und Verbrauch von Energie (U.2) .....               | 145 |
| 3.2.52.1 | <b>Water</b> .....  | 145 | 3.2.52.1 | Wasser.....   | 145 |
| 3.2.52.2 | <b>Air emissions</b> .....                                  | 145 | 3.2.52.2 | Luftemissionen.....   | 145 |
| 3.2.52.3 | <b>Solid output</b> .....                                   | 146 | 3.2.52.3 | Abgegebene Feststoffe.....                                    | 146 |
| 3.2.52.4 | <b>Noise</b> .....  | 146 | 3.2.52.4 | Lärm.....   | 146 |
| 3.2.53   | <b>Water use (U.3)</b> .....                                | 146 | 3.2.53   | Wasserverbrauch (U.3).....                                    | 146 |
| 3.2.53.1 | <b>Water</b> .....  | 146 | 3.2.53.1 | Wasser.....   | 146 |
| 3.2.53.2 | <b>Solid output</b> .....                                   | 146 | 3.2.53.2 | Abgegebene Feststoffe.....                                    | 146 |
| 3.2.54   | <b>Vacuum generation (U.4)</b> .....                        | 146 | 3.2.54   | Vakuumerzeugung (U.4).....                                    | 146 |

|           |   |     |           |   |     |
|-----------|---|-----|-----------|---|-----|
| 3.2.54.1  | <b>Water</b> .....  | 146 | 3.2.54.1  | Wasser .....  | 146 |
| 3.2.54.2  | <b>Air emissions</b> .....  | 146 | 3.2.54.2  | Luftemissionen .....                                    | 146 |
| 3.2.54.3  | <b>Energy</b> .....   | 147 | 3.2.54.3  | Energie.....  | 147 |
| 3.2.54.4  | <b>Noise</b> .....  | 147 | 3.2.54.4  | Lärm .....  | 147 |
| 3.2.55    | <b>Refrigeration (U.5)</b> .....  | 147 | 3.2.55    | Kühlen (U.5).....                                       | 147 |
| 3.2.55.1  | <b>Water</b> .....  | 147 | 3.2.55.1  | Wasser .....  | 147 |
| 3.2.55.2  | <b>Air emissions</b> .....  | 147 | 3.2.55.2  | Luftemissionen .....                                    | 147 |
| 3.2.55.3  | <b>Energy</b> .....   | 147 | 3.2.55.3  | Energie.....  | 147 |
| 3.2.55.4  | <b>Noise</b> .....  | 147 | 3.2.55.4  | Lärm .....  | 147 |
| 3.2.56    | <b>Compressed air generation (U.6)</b> .....                                    | 147 | 3.2.56    | Erzeugung von Druckluft (U.6).....                      | 147 |
| 3.2.56.1  | <b>Air emissions</b> .....  | 147 | 3.2.56.1  | Luftemissionen .....                                    | 147 |
| 3.2.56.2  | <b>Energy</b> .....   | 147 | 3.2.56.2  | Energie.....  | 147 |
| 3.2.56.3  | <b>Noise</b> .....  | 147 | 3.2.56.3  | Lärm .....  | 147 |
| 3.3       |   |     | 3.3       | Verbrauchs- und Emissionspegel in<br>einigen bestimmten |     |
|           | <b>Consumption and emission levels<br/>in some individual FDM sectors</b> ..... | 147 |           | NahrungsmittelBranchen.....                             | 147 |
| 3.3.1     | <b>Meat and poultry</b> .....   | 150 | 3.3.1     | Fleisch und Geflügel.....                               | 150 |
| 3.3.1.1   | <b>General information</b> .....  | 150 | 3.3.1.1   | Allgemeine Informationen.....                           | 150 |
| 3.3.1.1.1 | <b>Water</b> .....  | 150 | 3.3.1.1.1 | Wasser .....  | 150 |
| 3.3.1.1.2 | <b>Air emissions</b> .....  | 150 | 3.3.1.1.2 | Luftemissionen .....                                    | 150 |
| 3.3.1.1.3 | <b>Solid output</b> .....   | 150 | 3.3.1.1.3 | Abgegebene Feststoffe .....                             | 150 |
| 3.3.1.1.4 | <b>Energy</b> .....   | 150 | 3.3.1.1.4 | Energie.....  | 150 |
| 3.3.1.2   | <b>Meat and poultry production</b> .....  | 150 | 3.3.1.2   | Fleisch- und Geflügelproduktion.....                    | 150 |
| 3.3.1.2.1 | <b>General information</b> .....  | 150 | 3.3.1.2.1 | Allgemeine Informationen.....                           | 150 |
| 3.3.1.2.2 | <b>Salami and sausage production</b> .....                                      | 152 | 3.3.1.2.2 | Salami- und Wurstherstellung .....                      | 152 |
| 3.3.1.3   |   |     | 3.3.1.3   | Konservieren von Fleisch und<br>Geflügel.....           | 153 |
|           | <b>Meat and poultry preservation</b> .....                                      | 153 |           | Tiefkühlen .....  | 153 |
| 3.3.1.3.1 | <b>Freezing</b> .....   | 153 | 3.3.1.3.1 | Tiefkühlen .....  | 153 |
| 3.3.1.3.2 | <b>Curing</b> .....   | 153 | 3.3.1.3.2 | Einsalzen .....   | 153 |
| 3.3.1.3.3 | <b>Smoking</b> .....  | 154 | 3.3.1.3.3 | Räuchern .....  | 154 |
| 3.3.1.3.4 | <b>Drying</b> .....   | 155 | 3.3.1.3.4 | Trocknen.....   | 155 |
| 3.3.1.3.5 | <b>Canning</b> .....  | 155 | 3.3.1.3.5 | Einmachen .....   | 155 |
| 3.3.2     | <b>Fish and shellfish</b> .....   | 155 | 3.3.2     | Fisch und Muscheln.....                                 | 155 |
| 3.3.2.1   | <b>Water consumption</b> .....  | 156 | 3.3.2.1   | Wasserverbrauch .....                                   | 156 |
| 3.3.2.2   | <b>Waste water</b> .....  | 156 | 3.3.2.2   | Abwasser .....  | 156 |
| 3.3.2.3   | <b>Solid output</b> .....   | 157 | 3.3.2.3   | Abgegebene Feststoffe .....                             | 157 |
| 3.3.2.4   | <b>Energy</b> .....   | 161 | 3.3.2.4   | Energie.....  | 161 |
| 3.3.3     | <b>Fruit and vegetables</b> .....   | 161 | 3.3.3     | Obst und Gemüse .....                                   | 161 |
| 3.3.3.1   | <b>Water consumption</b> .....  | 161 | 3.3.3.1   | Wasserverbrauch .....                                   | 161 |
| 3.3.3.2   | <b>Waste water</b> .....  | 164 | 3.3.3.2   | Abwasser .....  | 164 |
| 3.3.3.3   | <b>Solid output</b> .....   | 169 | 3.3.3.3   | Abgegebene Feststoffe .....                             | 169 |
| 3.3.3.4   | <b>Energy</b> .....   | 172 | 3.3.3.4   | Energie.....  | 172 |
| 3.3.3.5   | <b>Data for some fruit and vegetable<br/>products</b> .....                     | 173 | 3.3.3.5   | Daten zu einigen Obst- und<br>Gemüseprodukten.....      | 173 |
| 3.3.3.5.1 | <b>Fresh-pack</b> .....   | 173 | 3.3.3.5.1 | Frisch verpackt .....                                   | 173 |
| 3.3.3.5.2 | <b>Preserved fruit and vegetables</b> .....                                     | 173 | 3.3.3.5.2 | Obst- und Gemüsekonserven.....                          | 173 |
| 3.3.3.5.3 | <b>Frozen vegetables</b> .....  | 175 | 3.3.3.5.3 | Tiefkühlgemüse .....                                    | 175 |
| 3.3.3.5.4 | <b>Juices</b> .....   | 178 | 3.3.3.5.4 | Säfte.....  | 178 |
| 3.3.3.5.5 | <b>Other products</b> .....   | 178 | 3.3.3.5.5 | Sonstige Produkte.....                                  | 178 |
| 3.3.4     | <b>Vegetable oils and fats</b> .....  | 178 | 3.3.4     | Pflanzliche Öle und Fette .....                         | 178 |
| 3.3.4.1   | <b>Water consumption</b> .....  | 178 | 3.3.4.1   | Wasserverbrauch .....                                   | 178 |
| 3.3.4.1.1 | <b>Olive oil</b> .....  | 178 | 3.3.4.1.1 | Olivenöl.....   | 178 |
| 3.3.4.2   | <b>Waste water</b> .....  | 178 | 3.3.4.2   | Abwasser .....  | 178 |
| 3.3.4.2.1 | <b>Olive oil</b> .....  | 180 | 3.3.4.2.1 | Olivenöl.....   | 180 |
| 3.3.4.3   | <b>Air emissions</b> .....  | 180 | 3.3.4.3   | Luftemissionen .....                                    | 180 |
| 3.3.4.4   | <b>Solid output</b> .....   | 181 | 3.3.4.4   | Abgegebene Feststoffe .....                             | 181 |
| 3.3.4.4.1 | <b>Oilseed</b> .....  | 183 | 3.3.4.4.1 | Ölsaaten.....   | 183 |
| 3.3.4.4.2 | <b>Olive oil</b> .....  | 184 | 3.3.4.4.2 | Olivenöl.....   | 184 |
| 3.3.4.5   | <b>Energy</b> .....   | 184 | 3.3.4.5   | Energie.....  | 184 |
| 3.3.4.6   | <b>Chemicals used</b> .....   | 185 | 3.3.4.6   | Verwendete Chemikalien .....                            | 185 |
| 3.3.5     | <b>Dairy products</b> .....   | 185 | 3.3.5     | Molkereiprodukte .....                                  | 185 |
| 3.3.5.1   | <b>Water</b> .....  | 185 | 3.3.5.1   | Wasser .....  | 185 |
| 3.3.5.1.1 | <b>Water consumption</b> .....  | 185 | 3.3.5.1.1 | Wasserverbrauch .....                                   | 185 |

|            |                                       |     |
|------------|---------------------------------------|-----|
| 3.3.5.1.2  | <b>Waste water</b> .....              | 187 |
| 3.3.5.2    | <b>Air emissions</b> .....            | 190 |
| 3.3.5.3    | <b>Solid output</b> .....             | 190 |
| 3.3.5.4    | <b>Energy</b> .....                   | 193 |
| 3.3.5.5    | <b>Consumption of chemicals</b> ..... | 194 |
| 3.3.5.6    | <b>Noise</b> .....                    | 195 |
| 3.3.6      | <b>Dry pasta</b> .....                | 195 |
| 3.3.6.1    | <b>Water</b> .....                    | 195 |
| 3.3.6.2    | <b>Emissions to air</b> .....         | 195 |
| 3.3.6.3    | <b>Energy</b> .....                   | 195 |
| 3.3.7      | <b>Starch</b> .....                   | 196 |
| 3.3.7.1    | <b>Water consumption</b> .....        | 196 |
| 3.3.7.2    | <b>Waste water</b> .....              | 196 |
| 3.3.7.3    | <b>Air emissions</b> .....            | 196 |
| 3.3.7.4    | <b>Solid output</b> .....             | 196 |
| 3.3.7.5    | <b>Energy</b> .....                   | 197 |
| 3.3.8      | <b>Sugar</b> .....                    | 197 |
| 3.3.8.1    | <b>Sugar beet</b> .....               | 197 |
| 3.3.8.1.1  | <b>Water consumption</b> .....        | 197 |
| 3.3.8.1.2  | <b>Waste water</b> .....              | 198 |
| 3.3.8.1.3  | <b>Solid output</b> .....             | 198 |
| 3.3.8.1.4  | <b>Energy</b> .....                   | 199 |
| 3.3.8.2    | <b>Cane sugar refining</b> .....      | 200 |
| 3.3.9      | <b>Coffee</b> .....                   | 200 |
| 3.3.10     | <b>Drinks</b> .....                   | 200 |
| 3.3.10.1   | <b>Water consumption</b> .....        | 200 |
| 3.3.10.2   | <b>Waste water</b> .....              | 200 |
| 3.3.10.2.1 | <b>Wine</b> .....                     | 201 |
| 3.3.10.2.2 | <b>Cider and perry</b> .....          | 201 |
| 3.3.11     | <b>Brewing</b> .....                  | 202 |
| 3.3.11.1   | <b>Water consumption</b> .....        | 203 |
| 3.3.11.2   | <b>Waste water</b> .....              | 203 |
| 3.3.11.3   | <b>Air emissions</b> .....            | 205 |
| 3.3.11.4   | <b>Solid output</b> .....             | 205 |
| 3.3.11.5   | <b>Energy</b> .....                   | 206 |
| 3.3.11.6   | <b>Noise</b> .....                    | 207 |
| 3.3.11.7   | <b>Solid output</b> .....             | 207 |
| 3.3.12     | <b>Citric acid</b> .....              | 207 |
| 3.3.12.1   | <b>Water consumption</b> .....        | 207 |
| 3.3.12.2   | <b>Waste water</b> .....              | 207 |
| 3.3.12.3   | <b>Solid output</b> .....             | 207 |
| 4          |                                       |     |

TECHNIQUES TO CONSIDER IN THE DETERMINATION OF BAT .... 209

|         |  |     |
|---------|--|-----|
| 4.1     | General techniques for the FDM sector .....                        | 211 |
| 4.1.1   | Environmental management tools .....                               | 211 |
| 4.1.2   | Optimise operation by providing training .....                     | 217 |
| 4.1.3   | Equipment design .....   | 218 |
| 4.1.3.1 | Design equipment to minimise consumption and emission levels ..... | 218 |
| 4.1.3.2 | Selection of efficient and quiet fans ....                         | 219 |
| 4.1.3.3 | Selection of fans with low numbers of blades .....                 | 220 |
| 4.1.3.4 | Designing pipework to minimise noise emissions .....               | 221 |
| 4.1.3.5 | Sound insulation of equipment .....                                | 222 |

|            |                            |     |
|------------|----------------------------|-----|
| 3.3.5.1.2  | Abwasser.....              | 187 |
| 3.3.5.2    | Luftemissionen.....        | 190 |
| 3.3.5.3    | Abgegebene Feststoffe..... | 190 |
| 3.3.5.4    | Energie .....              | 193 |
| 3.3.5.5    | Chemikalienverbrauch ..... | 194 |
| 3.3.5.6    | Lärm.....                  | 195 |
| 3.3.6      | Trockene Nudelwaren.....   | 195 |
| 3.3.6.1    | Wasser.....                | 195 |
| 3.3.6.2    | Emissionen in Luft.....    | 195 |
| 3.3.6.3    | Energie .....              | 195 |
| 3.3.7      | Stärke .....               | 196 |
| 3.3.7.1    | Wasserverbrauch.....       | 196 |
| 3.3.7.2    | Abwasser.....              | 196 |
| 3.3.7.3    | Luftemissionen.....        | 196 |
| 3.3.7.4    | Abgegebene Feststoffe..... | 196 |
| 3.3.7.5    | Energie .....              | 197 |
| 3.3.8      | Zucker .....               | 197 |
| 3.3.8.1    | Zuckerrüben .....          | 197 |
| 3.3.8.1.1  | Wasserverbrauch.....       | 197 |
| 3.3.8.1.2  | Abwasser.....              | 198 |
| 3.3.8.1.3  | Abgegebene Feststoffe..... | 198 |
| 3.3.8.1.4  | Energie .....              | 199 |
| 3.3.8.2    | Rohrzuckerraffination..... | 200 |
| 3.3.9      | Kaffee .....               | 200 |
| 3.3.10     | Getränke.....              | 200 |
| 3.3.10.1   | Wasserverbrauch.....       | 200 |
| 3.3.10.2   | Abwasser.....              | 200 |
| 3.3.10.2.1 | Wein.....                  | 201 |
| 3.3.10.2.2 | Cidre und Birnenmost.....  | 201 |
| 3.3.11     | Brauwirtschaft.....        | 202 |
| 3.3.11.1   | Wasserverbrauch.....       | 203 |
| 3.3.11.2   | Abwasser.....              | 203 |
| 3.3.11.3   | Luftemissionen.....        | 205 |
| 3.3.11.4   | Abgegebene Feststoffe..... | 205 |
| 3.3.11.5   | Energie .....              | 206 |
| 3.3.11.6   | Lärm.....                  | 207 |
| 3.3.11.7   | Abgegebene Feststoffe..... | 207 |
| 3.3.12     | Zitronensäure .....        | 207 |
| 3.3.12.1   | Wasserverbrauch.....       | 207 |
| 3.3.12.2   | Abwasser.....              | 207 |
| 3.3.12.3   | Abgegebene Feststoffe..... | 207 |
| 4          |                            |     |

**BEI DER FESTLEGUNG VON BVT ZU**

**BERÜCKSICHTIGENDE**

|         |   |     |
|---------|---|-----|
|         | <b>TECHNIKEN</b> .....  | 209 |
| 4.1     | <b>Allgemeine Techniken für die Nahrungsmittelproduktion</b> .....            | 211 |
| 4.1.1   | <b>Umweltmanagement-Werkzeuge</b> .....                                       | 211 |
| 4.1.2   | <b>Optimierung des Betriebs durch Schulungen</b> .....                        | 217 |
| 4.1.3   | <b>Planung von Maschinen, Ausrüstung und Einrichtung</b> .....                | 218 |
| 4.1.3.1 | <b>Planung zur Reduzierung von Verbrauchs- und Emissionswerten</b> .....      | 218 |
| 4.1.3.2 | <b>Auswahl effizienter und geräuscharmer Ventilatoren</b> .....               | 219 |
| 4.1.3.3 | <b>Auswahl von Ventilatoren mit geringer1F Schaufelzahl</b> .....             | 220 |
| 4.1.3.4 | <b>Planung von Rohrleitungen zur Minimierung von Geräuschemissionen</b> ..... | 221 |
| 4.1.3.5 | <b>Schallisolierung von Geräten</b> .....                                     | 222 |

|           |   |     |           |   |     |
|-----------|---|-----|-----------|---|-----|
| 4.1.3.6   | Position equipment to direct noise away from neighbours.....  | 223 | 4.1.3.6   | <b>Positionierung von Geräten so, dass der Schall nicht auf Anrainer gerichtet ist.....</b>                           | 223 |
| 4.1.4     | Installation design considerations .....  | 223 | 4.1.4     | <b>Aspekte bei der Anlagenplanung .....</b>   | 224 |
| 4.1.4.1   | Sound insulation of buildings.....  | 224 | 4.1.4.1   | <b>Schallsolierung von Gebäuden .....</b>   | 224 |
| 4.1.4.2   | Shielding buildings from noise immission sites.....   | 225 | 4.1.4.2   | <b>Abschirmung von Gebäuden gegen Lärmimmissionsbereiche .....</b>  | 225 |
| 4.1.4.3   | Application of a spiral turbulence generator to a chimney to minimise noise emissions .....                     | 225 | 4.1.4.3   | <b>Installation eines Spiralturbulenzgenerators an einem Schornstein zur Minderung von Lärmemissionen .....</b>       | 226 |
| 4.1.5     | Maintenance.....  | 226 | 4.1.5     | <b>Wartung .....</b>  | 226 |
| 4.1.6     | Methodology for preventing and minimising the consumption of water and energy and the production of waste ..... | 227 | 4.1.6     | <b>Methodik für die Vermeidung und Verminderung von Wasser- und Energieverbrauch und Abfallerzeugung.....</b>         | 228 |
| 4.1.6.1   | Step 1: Obtaining management commitment, organisation and planning .....  | 231 | 4.1.6.1   | <b>Schritt 1: Engagement des Managements sowie Organisation und Planung durch das Management.....</b>                 | 231 |
| 4.1.6.2   | Step 2: Analysis of production processes .....  | 232 | 4.1.6.2   | <b>Schritt 2: Analyse der Produktionsprozesse.....</b>  | 232 |
| 4.1.6.2.1 | Analysis of production processes aimed at the prevention and minimisation of water consumption....              | 233 | 4.1.6.2.1 | <b>Untersuchung von Produktionsprozessen mit dem Ziel der Vermeidung und Verminderung des Wasserverbrauchs .....</b>  | 233 |
| 4.1.6.2.2 | Analysis of production processes aimed at the prevention and minimisation of energy consumption..               | 234 | 4.1.6.2.2 | <b>Untersuchung von Produktionsprozessen mit dem Ziel der Vermeidung und Verminderung des Energieverbrauchs .....</b> | 234 |
| 4.1.6.2.3 | Analysis of production processes aimed at the prevention and minimisation of waste production.....              | 235 | 4.1.6.2.3 | <b>Untersuchung von Produktionsprozessen mit dem Ziel der Vermeidung und Verminderung der Abfallerzeugung.....</b>    | 235 |
| 4.1.6.3   | Step 3: Assessment of objectives .....  | 238 | 4.1.6.3   | <b>Schritt 3: Bewertung von Zielsetzungen.....</b>  | 238 |
| 4.1.6.4   | Step 4: Identifying prevention and minimisation options.....  | 238 | 4.1.6.4   | <b>Schritt 4: Aufzeigen von Möglichkeiten zur Vermeidung und Verminderung .....</b>                                   | 238 |
| 4.1.6.4.1 | Pinch technology.....   | 239 | 4.1.6.4.1 | <b>Pinch-Technologie .....</b>  | 239 |
| 4.1.6.5   | Step 5: Carry out an evaluation and feasibility study.....  | 240 | 4.1.6.5   | <b>Schritt 5: Erstellung einer Evaluierungs- und Machbarkeitsstudie .....</b>   | 240 |
| 4.1.6.6   | Step 6: Implementing the prevention and minimisation programme .....  | 241 | 4.1.6.6   | <b>Schritt 6: Umsetzung des Vermeidungs- und Verminderungsprogramms .....</b>   | 241 |
| 4.1.6.7   | Step 7: Ongoing monitoring by measurement and visual inspection....   | 241 | 4.1.6.7   | <b>Schritt 7: Laufende Überwachung durch Messungen und Sichtprüfungen .....</b>                                       | 241 |
| 4.1.7     | Production management techniques....  | 243 | 4.1.7     | <b>Techniken für das Produktionsmanagement .....</b>  | 243 |
| 4.1.7.1   | Apply production planning, to minimise associated waste production and cleaning frequencies...                  | 243 | 4.1.7.1   | <b>Produktionsplanung zur Reduzierung der Abfallentstehung und Reinigungshäufigkeit .....</b>                         | 243 |
| 4.1.7.2   | Receive materials in bulk .....   | 244 | 4.1.7.2   | <b>Anlieferung von Material in großen Mengen .....</b>  | 244 |
| 4.1.7.3   | Minimise storage times for perishable materials.....  | 244 | 4.1.7.3   | <b>Minimierung der Lagerzeiten verderblicher Stoffe.....</b>  | 245 |
| 4.1.7.4   | Transport solid materials dry .....   | 246 | 4.1.7.4   | <b>Trockentransport von Feststoffen....</b>   | 246 |

|           |   |     |           |  |     |
|-----------|---|-----|-----------|--|-----|
| 4.1.7.5   | Use a waste management team.....  | 247 | 4.1.7.5   | <b>Einsatz eines Abfallmanagementteams.....</b>  | 247 |
| 4.1.7.6   |   |     | 4.1.7.6   | <b>Trennung der anfallenden Stoffe zur Optimierung von Verbrauch, Verwertung, Rückgewinnung, Kreislaufführung und Entsorgung (sowie zur Reduzierung von Wasserverbrauch und Abwasseranfall).....</b> | 248 |
|           | Segregation of outputs, to optimise use, re-use, recovery, recycling and disposal (and minimise water use and waste water contamination)..... | 248 | 4.1.7.7   | <b>Verwendung von Nebenprodukten, Koprodukten und Rückständen als Tierfutter.....</b>  | 251 |
| 4.1.7.7   | Use of by-products, co-products and residues as animal feed.....  | 250 | 4.1.7.8   | <b>Trennung von Abwasserströmen zur Optimierung von Wiederverwendung und Nachbehandlung.....</b>   | 252 |
| 4.1.7.8   | Segregation of water streams to optimise re-use and treatment.....  | 253 | 4.1.7.9   | <b>Reduzierung von Heiz- und Kühlzeiten.....</b>   | 254 |
| 4.1.7.9   | Minimise heating and cooling times....  | 254 | 4.1.7.10  | <b>Optimierung von An- und Abfahrprozessen und anderer spezieller Betriebssituationen.....</b>   | 255 |
| 4.1.7.10  | Optimise start-up and shut-down procedures and other special operating situations.....  | 255 | 4.1.7.11  | <b>Gute handwerkliche Praxis.....</b>  | 255 |
| 4.1.7.11  | Good housekeeping.....  | 255 | 4.1.7.12  | <b>Geordnete Fahrzeugbewegungen am Standort.....</b>   | 255 |
| 4.1.7.12  | Manage on-site vehicle movements ....   | 255 | 4.1.8     | <b>Techniken für die Prozesssteuerung.....</b>   | 257 |
| 4.1.8     | Process control techniques .....  | 257 | 4.1.8.1   | <b>Temperaturregelung durch spezielle Messungen und Korrekturen .....</b>  | 258 |
| 4.1.8.1   | Control temperature, by dedicated measurement and correction.....   | 257 | 4.1.8.2   | <b>Steuerung der Durchflussmenge oder Füllstandshöhe durch eigene Druckmessungen.....</b>  | 259 |
| 4.1.8.2   | Control flow or level, by dedicated measurement of pressure .....   | 258 | 4.1.8.3   | <b>Füllstandsmessung .....</b>   | 259 |
| 4.1.8.3   | Level measurement.....  | 259 | 4.1.8.4   | <b>Durchflussmessung und -regulierung .....</b>  | 261 |
| 4.1.8.4   | Flow measurement and control .....  | 260 | 4.1.8.5   | <b>Analytische Messungen .....</b>   | 263 |
| 4.1.8.5   | Analytical measurement.....   | 262 | 4.1.8.5.1 | <b>pH-Messung.....</b>   | 263 |
| 4.1.8.5.1 | pH measurement.....   | 262 | 4.1.8.5.2 | <b>Leitfähigkeitsmessung .....</b>   | 264 |
| 4.1.8.5.2 | Conductivity measurement.....   | 263 | 4.1.8.5.3 | <b>Trübungsmessung.....</b>  | 266 |
| 4.1.8.5.3 | Turbidity measurement.....  | 265 | 4.1.8.6   | <b>Einsatz automatischer Wasserregler.....</b>   | 268 |
| 4.1.8.6   | Use automated water start/stop controls.....  | 267 | 4.1.8.7   | <b>Einsatz von Regelungsvorrichtungen.....</b>   | 268 |
| 4.1.8.7   | Use of control devices .....  | 268 | 4.1.8.8   | <b>Einsatz von Wasserdüsen .....</b>   | 269 |
| 4.1.8.8   | Use of water nozzles.....   | 269 | 4.1.9     | <b>Materialauswahl.....</b>  | 271 |
| 4.1.9     | Selection of materials .....  | 270 | 4.1.9.1   | <b>Auswahl von Rohmaterial für die Nahrungsmittelproduktion zur Minimierung von festen Abfällen und schädlichen Emissionen in Luft und Wasser.....</b>   | 271 |
| 4.1.9.1   | Selection of raw FDM materials which minimise solid waste and harmful emissions to air and water.....   | 270 | 4.1.9.2   | <b>Auswahl der verwendeten Hilfsmaterialien.....</b>   | 272 |
| 4.1.9.2   | Selection of auxiliary materials used...  | 271 | 4.1.9.3   | <b>Vermeidung des Gebrauchs von Ozonschicht schädigenden Stoffen, wie z. B. halogenierten Kältemitteln.....</b>  | 272 |
| 4.1.9.3   | Avoiding the use of ozone depleting substances, such as halogenated refrigerants .....  | 271 | 4.2       | <b>Techniken, die in einer Reihe von Branchen der Nahrungsmittelproduktion anwendbar sind (strukturiert wie Kapitel 2 und 3) ....</b>  | 273 |
| 4.2       | Techniques applicable in a number of FDM sectors (reflects the structure of Chapters 2 and 3) .....   | 272 | 4.2.1     | <b>Annahme, Handhabung und Lagerung von Material.....</b>  | 273 |
| 4.2.1     | Materials reception, handling and storage .....   | 272 |           |  |     |

|         |   |     |         |  |     |
|---------|---|-----|---------|--|-----|
| 4.2.1.1 | Switch off the engine and refrigerator unit of a vehicle during loading/unloading and when parked ...           | 272 | 4.2.1.1 | <b>Abschalten von Motor und Kühleinheit von Fahrzeugen beim Be- und Entladen und im geparkten Zustand.....</b>   | 273 |
| 4.2.2   | Thawing .....   | 272 | 4.2.2   | <b>Auftauen .....</b>  | 273 |
| 4.2.2.1 | Thawing using recirculation and air stirring .....  | 272 | 4.2.2.1 | <b>Auftauen mittels Rückführung und Bewegung mit Luft.....</b>   | 273 |
| 4.2.2.2 | Thawing in containers filled with warm water with air bubbles at the bottom .....                               | 273 | 4.2.2.2 | <b>Auftauen in Behältern mit warmem Wasser und Luftblasen am Boden.....</b>  | 273 |
| 4.2.2.3 | Thawing by sprinkling .....   | 273 | 4.2.2.3 | <b>Auftauen durch Berieselung.....</b>   | 274 |
| 4.2.2.4 | Thawing by 100 % water saturated heated air .....   | 274 | 4.2.2.4 | <b>Auftauen mit 100 % wassergesättigter gewärmter Luft....</b>   | 274 |
| 4.2.2.5 | Thawing in air .....  | 274 | 4.2.2.5 | <b>Auftauen an der Luft.....</b>   | 275 |
| 4.2.3   | Centrifugation/separation .....   | 275 | 4.2.3   | <b>Zentrifugation/Separation .....</b>   | 275 |
| 4.2.3.1 | Minimisation of centrifugal separator waste discharges .....  | 275 | 4.2.3.1 | <b>Minimierung des Anfalls von Abfall aus Zentrifugalabscheidern...</b>  | 275 |
| 4.2.4   | Fermentation .....  | 275 | 4.2.4   | <b>Fermentierung .....</b>   | 276 |
| 4.2.4.1 | Carbon dioxide recovery and purification .....  | 275 | 4.2.4.1 | <b>Rückgewinnung und Aufreinigung von Kohlendioxid.....</b>  | 276 |
| 4.2.5   | Smoking .....   | 277 | 4.2.5   | <b>Räuchern .....</b>  | 277 |
| 4.2.5.1 | Smoke from burning wood .....   | 277 | 4.2.5.1 | <b>Rauch von brennendem Holz .....</b>   | 278 |
| 4.2.5.2 | Smoke from smouldering wood .....   | 278 | 4.2.5.2 | <b>Rauch von schwelendem Holz .....</b>  | 279 |
| 4.2.5.3 | Liquid smoke .....  | 279 | 4.2.5.3 | <b>Flüssigrauch .....</b>  | 279 |
| 4.2.5.4 | Friction smoke .....  | 279 | 4.2.5.4 | <b>Friktionsrauch .....</b>  | 280 |
| 4.2.5.5 | Smoke from superheated steam .....  | 280 | 4.2.5.5 | <b>Rauch aus überhitztem Dampf.....</b>  | 281 |
| 4.2.6   | Cooking.....  | 280 | 4.2.6   | <b>Garen .....</b>   | 281 |
| 4.2.6.1 | Water bath oven – cooking water.....  | 280 | 4.2.6.1 | <b>Wasserbadautoklav – Garwasser ....</b>  | 281 |
| 4.2.6.2 | Water bath oven – using water instead of brine.....   | 281 | 4.2.6.2 | <b>Wasserbadautoklav – Verwendung von Wasser statt Lake .....</b>  | 282 |
| 4.2.6.3 | Shower oven.....  | 281 | 4.2.6.3 | <b>Berieselungsautoklav.....</b>   | 282 |
| 4.2.6.4 | Steam oven.....   | 281 | 4.2.6.4 | <b>Dampfautoklav .....</b>   | 282 |
| 4.2.6.5 | Hot air oven.....   | 282 | 4.2.6.5 | <b>Heißluftautoklav .....</b>  | 283 |
| 4.2.6.6 | Microwave oven.....   | 282 | 4.2.6.6 | <b>Mikrowellenautoklav .....</b>   | 283 |
| 4.2.7   | Frying.....   | 282 | 4.2.7   | <b>Frittieren .....</b>  | 283 |
| 4.2.7.1 | Recirculate and burn exhaust gases.....   | 282 | 4.2.7.1 | <b>Rezirkulation und Verbrennung von Abgasen .....</b>   | 283 |
| 4.2.8   | Preservation in cans, bottles and jars ..   | 283 | 4.2.8   | <b>Konservierung in Dosen, Flaschen und Gläsern.....</b>   | 284 |
| 4.2.8.1 | Avoiding cooking before preservation in cans, bottles and jars, if food can be cooked during sterilisation..... | 283 | 4.2.8.1 | <b>Vermeiden des Garens vor dem Konservieren in Dosen, Flaschen und Gläsern, wenn die Lebensmittel während der Sterilisierung gegart werden können .....</b> | 284 |
| 4.2.8.2 | Automated filling incorporating recycling of spillages .....  | 284 | 4.2.8.2 | <b>Automatische Befüllung mit Rückführung übergelaufener Produkte .....</b>  | 285 |
| 4.2.8.3 | Recovery of floating oil when washing filled cans, bottles and jars....   | 284 | 4.2.8.3 | <b>Rückgewinnung von aufschwimmendem Öl beim Waschen gefüllter Dosen, Flaschen und Gläser .....</b>  | 285 |
| 4.2.8.4 | Batch sterilisation after filling of cans, bottles and jars .....   | 284 | 4.2.8.4 | <b>Chargensterilisierung nach der Befüllung von Dosen, Flaschen und Gläsern.....</b>   | 285 |
| 4.2.8.5 | Continuous sterilisation after filling of cans, bottles and jars .....  | 285 | 4.2.8.5 | <b>Kontinuierliche Sterilisierung nach der Befüllung von Dosen, Flaschen und Gläsern.....</b>  | 286 |
| 4.2.9   | Evaporation .....   | 286 | 4.2.9   | <b>Verdampfung .....</b>   | 287 |
| 4.2.9.1 | Multistage evaporation.....   | 287 | 4.2.9.1 | <b>Mehrstufige Verdampfung .....</b>   | 288 |
| 4.2.9.2 | Vapour compression/recompression ...  | 288 | 4.2.9.2 | <b>Brüdenverdichtung.....</b>  | 289 |

|            |  |     |            |  |     |
|------------|--|-----|------------|--|-----|
| 4.2.9.2.1  | Mechanical vapour recompression (MVR).....   | 289 | 4.2.9.2.1  | <b>Mechanische Brüdenverdichtung (MBV) .....</b>   | 290 |
| 4.2.9.2.2  | Thermal vapour recompression (TVR).....  | 291 | 4.2.9.2.2  | <b>Thermische Brüdenverdichtung (TBV) .....</b>  | 292 |
| 4.2.10     | Cooling.....   | 292 | 4.2.10     | <b>Kühlung .....</b>   | 293 |
| 4.2.10.1   |  |     | 4.2.10.1   | <b>Einsatz eines Plattenwärmetauschers für das Vorkühlen von Eiswasser mit Ammoniak .....</b>  | 293 |
| 4.2.10.2   | Using a plate heat-exchanger for precooling ice-water with ammonia ....                            | 292 | 4.2.10.2   | <b>Vorkühlung von Eiswasser mit kaltem Wasser aus einem Fluss oder See .....</b>   | 294 |
| 4.2.10.3   | Using cold water from a river or lake for precooling ice-water.....                                | 293 | 4.2.10.3   | <b>Geschlossener Kühlkreislauf.....</b>  | 294 |
| 4.2.11     | Freezing.....  | 295 | 4.2.11     | <b>Tiefkühlung .....</b>   | 295 |
| 4.2.11.1   | Energy efficiency in deep freezing.....  | 295 | 4.2.11.1   | <b>Energieeffizienz beim Tiefkühlen .....</b>  | 296 |
| 4.2.11.2   |  |     | 4.2.11.2   | <b>Reduzierung des Kondensationsdrucks .....</b>   | 296 |
| 4.2.11.3   | Lowering condensation pressure .....   | 295 | 4.2.11.3   | <b>Reduzierung der Kondensationstemperatur.....</b>  | 296 |
| 4.2.11.4   | Lowering condensation temperature ...  | 295 | 4.2.11.4   | <b>Erhöhung der Verdampfungstemperatur.....</b>  | 297 |
| 4.2.11.5   | Raising evaporation temperature .....  | 296 | 4.2.11.5   | <b>Verwendung hocheffizienter Motoren zum Antrieb von Gebläsen.....</b>  | 298 |
| 4.2.11.6   | Using high efficiency motors for driving fans.....   | 297 | 4.2.11.6   | <b>Verringerung der Gebläseleistung während kurzer Produktionspausen .....</b>   | 298 |
| 4.2.11.7   | Reducing the fan output during short production stops .....  | 298 | 4.2.11.7   | <b>Betrieb ohne automatisches Abtauen während kurzer Produktionspausen .....</b>   | 299 |
| 4.2.12     | Operating without automatic defrosting during short production stops.....                          | 298 | 4.2.12     | <b>Verpacken und Befüllen .....</b>  | 299 |
| 4.2.12.1   | Packing and filling.....   | 299 | 4.2.12.1   | <b>Auswahl des Verpackungsmaterials.....</b>   | 299 |
| 4.2.12.2   | Selection of packaging materials.....  | 299 | 4.2.12.2   | <b>Optimierung des Verpackungsdesigns zur Mengenreduktion.....</b>   | 300 |
| 4.2.12.3   | Optimisation of packaging design – to reduce the quantity .....                                    | 300 | 4.2.12.3   | <b>Trennung von Verpackungsmaterial zur Optimierung von Gebrauch, Wiederverwendung, Rückgewinnung, Wiederverwertung und Entsorgung .....</b> | 301 |
| 4.2.12.4   | Segregation of packaging materials to optimise use, re-use, recovery, recycling and disposal ..... | 301 | 4.2.12.4   | <b>Optimierung der Effizienz von Verpackungslinien .....</b>   | 303 |
| 4.2.12.5   | Optimising packing line efficiency.....  | 302 | 4.2.12.5   | <b>Abfallminimierung durch Optimierung der Geschwindigkeit von Verpackungslinien .....</b>   | 304 |
| 4.2.12.6   | Waste minimisation by optimising packing line speed .....  | 303 | 4.2.12.6   | <b>Einsatz von Kontrollwaagen in der Prozesslinie zur Vermeidung von Verpackungsüberfüllungen.....</b>                                       | 304 |
| 4.2.13     | Use of in-line check-weighers to prevent overfilling of packaging .....                            | 303 | 4.2.13     | <b>Erzeugung und Verbrauch von Energie .....</b>   | 305 |
| 4.2.13.1   | Energy generation and consumption ...  | 304 | 4.2.13.1   | <b>Kraft-Wärme-Kopplung (KWK) – Überblick über die Situation in Europa .....</b>   | 305 |
| 4.2.13.1.1 | Combined heat and power generation (CHP).....  | 304 | 4.2.13.1.1 | <b>Kraft-Wärme-Kopplung (KWK) .....</b>  | 305 |
| 4.2.13.2   | Efficiency of a heat generator.....  | 308 | 4.2.13.2   | <b>Effizienz von Wärmeerzeugern .....</b>  | 308 |
| 4.2.13.2.1 | Improving the efficiency of a heat generator.....  | 309 | 4.2.13.2.1 | <b>Verbesserung der Effizienz von Wärmeerzeugern .....</b>   | 309 |
| 4.2.13.3   | Insulation of pipes, vessels and equipment.....  | 310 | 4.2.13.3   | <b>Isolierung von Leitungen, Gefäßen und Ausrüstungen .....</b>  | 309 |
| 4.2.13.4   | Heat pumps for heat recovery.....  | 310 | 4.2.13.4   | <b>Wärmepumpen für die Wärmerückgewinnung .....</b>  | 310 |

|           |  |     |           |  |     |
|-----------|--|-----|-----------|--|-----|
| 4.2.13.5  | Heat recovery from cooling systems...  | 311 | 4.2.13.5  | <b>Wärmerückgewinnung aus Kühlsystemen.....</b>  | 311 |
| 4.2.13.6  | Switch off equipment when it is not needed .....   | 312 | 4.2.13.6  | <b>Abschalten nicht benötigter Ausrüstungen .....</b>  | 312 |
| 4.2.13.7  | Reduce the loads on motors .....   | 312 | 4.2.13.7  | <b>Verringerung der Belastung von Motoren .....</b>  | 312 |
| 4.2.13.8  | Minimise motor losses .....  | 313 | 4.2.13.8  | <b>Reduzierung von Verlusten bei Motoren .....</b>   | 313 |
| 4.2.13.9  | Frequency converters on motors .....   | 313 | 4.2.13.9  | <b>Frequenzwandler bei Motoren .....</b>   | 313 |
| 4.2.13.10 | Use variable speed drives to reduce the load on fans and pumps.....                                    | 314 | 4.2.13.10 | <b>Einsatz von Verstellgetrieben zur Verringerung der Belastung von Ventilatoren und Pumpen .....</b>                    | 314 |
| 4.2.14    | Water use .....  | 315 | 4.2.14    | <b>Verwendung von Wasser .....</b>   | 315 |
| 4.2.14.1  | Only pump up water that is required...   | 315 | 4.2.14.1  | <b>Nicht mehr Wasser fördern als nötig .....</b>   | 315 |
| 4.2.15    | Refrigeration and air conditioning .....   | 315 | 4.2.15    | <b>Kühlung und Klimatisierung.....</b>   | 315 |
| 4.2.15.1  | Optimising air conditioning and cold storage temperatures .....  | 315 | 4.2.15.1  | <b>Optimierung der Temperatur bei der Klimatisierung und in Kühllagern .....</b>   | 315 |
| 4.2.15.2  | Minimising transmission and ventilation losses from cooled rooms, coldstores and freezing tunnels..... | 316 | 4.2.15.2  | <b>Minimierung von Transmissions- und Ventilationsverlusten aus gekühlten Räumen, Kühllagern und Gefriertunneln.....</b> | 316 |
| 4.2.15.3  | Regularly defrosting the entire system .....   | 317 | 4.2.15.3  | <b>Regelmäßiges Abtauen des gesamten Systems .....</b>   | 316 |
| 4.2.15.4  | Optimisation of the defrosting cycle ...   | 317 | 4.2.15.4  | <b>Optimierung des Abtauzyklus .....</b>   | 317 |
| 4.2.15.5  | Automatic defrosting of cooling evaporators in cold storage.....                                       | 317 | 4.2.15.5  | <b>Automatisches Abtauen von Kühlverdampfern in Kaltlagerbereichen .....</b>   | 317 |
| 4.2.15.6  | Use of binary ice as a cooling fluid (secondary refrigerant).....                                      | 318 | 4.2.15.6  | <b>Verwendung von Binäreis als Kühlflüssigkeit (sekundäres Kältemittel) .....</b>  | 318 |
| 4.2.16    | Compressed air generation and use.....   | 320 | 4.2.16    | <b>Erzeugung und Verwendung von Druckluft .....</b>  | 320 |
| 4.2.16.1  | Optimise pressure settings .....   | 320 | 4.2.16.1  | <b>Optimierung der Druckeinstellungen.....</b>   | 320 |
| 4.2.16.2  | Optimise the air inlet temperature.....  | 321 | 4.2.16.2  | <b>Optimierung der Temperatur der zugeführten Luft.....</b>  | 320 |
| 4.2.16.3  | Fit silencers to air inlets and exhausts.....  | 321 | 4.2.16.3  | <b>Ausstattung von Luftern- und -auslässen mit Schalldämpfern.....</b>   | 321 |
| 4.2.17    | Steam systems .....  | 322 | 4.2.17    | <b>Dampfsysteme .....</b>  | 322 |
| 4.2.17.1  | Maximise condensate return .....   | 322 | 4.2.17.1  | <b>Maximierung der Kondensatrückführung.....</b>   | 322 |
| 4.2.17.2  | Avoid losses of flash steam from condensate return .....   | 322 | 4.2.17.2  | <b>Vermeidung der Verluste von Entspannungsampf aus der Kondensatrückführung.....</b>                                    | 322 |
| 4.2.17.3  | Isolate unused/infrequently used pipework .....  | 323 | 4.2.17.3  | <b>Abtrennung von selten oder gar nicht verwendeten Rohrleitungen ....</b>   | 323 |
| 4.2.17.4  | Minimising the blowdown of a boiler .....  | 323 | 4.2.17.4  | <b>Minimierung des Abblasens von Kesseln .....</b>   | 323 |
| 4.3       | Cleaning .....   | 324 | 4.3       | <b>Reinigung .....</b>   | 324 |
| 4.3.1     | Dry cleaning of equipment and installations .....  | 324 | 4.3.1     | <b>Trockene Reinigung von Geräten und Anlagen .....</b>  | 324 |
| 4.3.1.1   | Provision and use of catchpots over floor drains .....   | 325 | 4.3.1.1   | <b>Bereitstellung und Verwendung von Filtereinsätzen an Bodenabläufen .....</b>  | 325 |
| 4.3.2     | Pre-soak floors and open equipment to loosen dirt before cleaning.....                                 | 326 | 4.3.2     | <b>Einweichen von Böden und offenen Geräten, um Schmutz vor der Reinigung zu lösen .....</b>                             | 326 |
| 4.3.3     | Pigging.....   | 326 | 4.3.3     | <b>Molchsysteme.....</b>   | 326 |

|           |  |     |           |   |     |
|-----------|--|-----|-----------|---|-----|
| 4.3.4     | Removal of residual materials from pipework, using compressed air, before cleaning or product change-over..... | 328 | 4.3.4     | <b>Entfernung von Restmaterial aus Rohrleitungen mittels Druckluft vor der Reinigung oder vor Produktwechsel.....</b> | 328 |
| 4.3.5     | Management of water, energy and detergents used .....  | 329 | 4.3.5     | <b>Wirtschaftlicher Umgang mit Wasser, Energie und Reinigungsmitteln .....</b>  | 329 |
| 4.3.6     | Fit cleaning hoses with hand operated triggers .....   | 330 | 4.3.6     | <b>Ausstattung von Reinigungsschläuchen mit Handauslösern.....</b>  | 330 |
| 4.3.7     | Pressure cleaning.....   | 330 | 4.3.7     | <b>Druckreinigung .....</b>   | 330 |
| 4.3.7.1   | Supply of pressure-controlled water and via nozzles .....  | 330 | 4.3.7.1   | <b>Versorgung mit druckreguliertem Wasser und über Düsen.....</b>   | 330 |
| 4.3.7.2   | High pressure cleaning using a centralised water ring main .....   | 331 | 4.3.7.2   | <b>Hochdruckreinigung unter Verwendung einer zentralen Ringleitung .....</b>  | 331 |
| 4.3.7.3   | Low pressure foam cleaning.....  | 332 | 4.3.7.3   | <b>Niederdruck-Schaumreinigung .....</b>  | 332 |
| 4.3.7.4   | Cleaning with gels .....   | 333 | 4.3.7.4   | <b>Gelreinigung.....</b>  | 333 |
| 4.3.8     | Selection of cleaning agents .....   | 334 | 4.3.8     | <b>Auswahl der Reinigungsmittel.....</b>  | 333 |
| 4.3.8.1   | Selection of disinfectants and sterilants .....  | 334 | 4.3.8.1   | <b>Auswahl von Desinfektions- und Sterilisationsmitteln .....</b>   | 334 |
| 4.3.8.2   | Use of chelating agents.....   | 334 | 4.3.8.2   | <b>Verwendung von Chelatbildnern .....</b>  | 334 |
| 4.3.8.2.1 | Using EDTA.....  | 335 | 4.3.8.2.1 | <b>Verwendung von EDTA .....</b>  | 335 |
| 4.3.8.2.2 | Known risks associated with using EDTA .....   | 335 | 4.3.8.2.2 | <b>Bekannte Risiken im Zusammenhang mit der Verwendung von EDTA .....</b>   | 335 |
| 4.3.8.2.3 | Not using EDTA.....  | 336 | 4.3.8.2.3 | <b>Verzicht auf EDTA .....</b>  | 336 |
| 4.3.8.2.4 | Reducing EDTA use by minimising milkstone formation by production planning.....                                | 336 | 4.3.8.2.4 | <b>Verringerung des EDTA-Gebrauchs durch Minimierung der Milchsteinbildung mittels Produktionsplanung .....</b>       | 336 |
| 4.3.8.2.5 | Example of a strategy to minimise the use of EDTA.....   | 337 | 4.3.8.2.5 | <b>Beispiel einer Strategie zur Minimierung des EDTA-Gebrauchs.....</b>   | 337 |
| 4.3.9     | CIP (cleaning-in-place) and its optimal use .....  | 338 | 4.3.9     | <b>CIP (Cleaning in Place) und ihr optimaler Einsatz .....</b>  | 338 |
| 4.3.10    | Frequent and prompt cleaning of processing equipment and materials storage areas .....                         | 341 | 4.3.10    | <b>Häufige und sofortige Reinigung von Prozessgeräten und Materiallagerbereichen .....</b>                            | 341 |
| 4.3.11    | Using metered water dispensers and/or high pressure low volume (HPLV) sprays for cleaning trucks.....          | 342 | 4.3.11    | <b>Verwendung von Hochdrucksprühreinigern (HPLV-Sprühvorrichtungen) zur Reinigung von Lastwagen .....</b>             | 342 |
| 4.4       | Techniques for minimising air emissions .....  | 342 | 4.4       | <b>Techniken zur Minimierung von Luftemissionen .....</b>   | 342 |
| 4.4.1     | Air emissions control strategy .....   | 342 | 4.4.1     | <b>Strategie zur Überwachung von Luftemissionen .....</b>   | 342 |
| 4.4.1.1   | Step 1: Definition of the problem.....   | 343 | 4.4.1.1   | <b>Schritt 1: Definition des Problems....</b>   | 343 |
| 4.4.1.1.1 | Odour example .....  | 344 | 4.4.1.1.1 | <b>Beispiel Geruch .....</b>  | 344 |
| 4.4.1.2   | Step 2: Inventory of site emissions.....   | 344 | 4.4.1.2   | <b>Schritt 2: Bestandsaufnahme der Emissionen der Betriebsstätte.....</b>   | 344 |
| 4.4.1.2.1 | Odour example .....  | 345 | 4.4.1.2.1 | <b>Beispiel Geruch .....</b>  | 344 |
| 4.4.1.3   | Step 3: Measurement of major emissions .....   | 346 | 4.4.1.3   | <b>Schritt 3: Messung wesentlicher Emissionen.....</b>  | 345 |
| 4.4.1.3.1 | Odour example .....  | 346 | 4.4.1.3.1 | <b>Beispiel Geruch .....</b>  | 346 |
| 4.4.1.4   | Step 4: Selection of air emission control techniques.....  | 347 | 4.4.1.4   | <b>Schritt 4: Auswahl von Techniken für die Begrenzung von Luftemissionen .....</b>                                   | 347 |
| 4.4.2     | Process-integrated techniques .....  | 347 | 4.4.2     | <b>Prozessintegrierte Techniken.....</b>  | 347 |
| 4.4.3     | End-of-pipe air treatment .....  | 347 | 4.4.3     | <b>Nachgeschaltete Luftbehandlung .....</b>   | 347 |
| 4.4.3.1   | Optimal use of air abatement equipment.....  | 349 | 4.4.3.1   | <b>Optimaler Einsatz von Abgasreinigungstechniken .....</b>   | 349 |

|            |  |     |            |   |     |
|------------|--|-----|------------|---|-----|
| 4.4.3.2    | Collection of air emissions at source<br>– local exhaust ventilation.....      | 349 | 4.4.3.2    | <b>Erfassen von Luftemissionen an<br/>der Quelle – örtliche Luftabzüge.....</b>                                 | 350 |
| 4.4.3.3    | Transport of ducted emissions to the<br>treatment or abatement equipment ..... | 351 | 4.4.3.3    | <b>Transport der Emissionen in<br/>Leitungen zur Behandlungs- oder<br/>Minderungseinrichtung.....</b>           | 351 |
| 4.4.3.4    | Selection of end-of-pipe<br>odour/VOCs abatement techniques.....               | 352 | 4.4.3.4    | <b>Auswahl von nachgeschalteten<br/>Techniken zur Minderung von<br/>Gerüchen/VOC .....</b>                      | 352 |
| 4.4.3.5    | Dynamic separation techniques.....   | 354 | 4.4.3.5    | <b>Schwerkraftabscheider .....</b>  | 355 |
| 4.4.3.5.1  | Separators.....  | 354 | 4.4.3.5.1  | <b>Massenkraftabscheider .....</b>  | 355 |
| 4.4.3.5.2  | Cyclones.....  | 355 | 4.4.3.5.2  | <b>Zyklone.....</b>   | 356 |
| 4.4.3.5.3  | Wet separation .....   | 356 | 4.4.3.5.3  | <b>Nassabscheidung.....</b>   | 357 |
| 4.4.3.6    | Electrostatic precipitators.....   | 359 | 4.4.3.6    | <b>Elektrostatische Abscheider .....</b>  | 360 |
| 4.4.3.7    | Filters .....  | 360 | 4.4.3.7    | <b>Filter .....</b>   | 361 |
| 4.4.3.7.1  | Tubular filters.....   | 361 | 4.4.3.7.1  | <b>Röhrenfilter.....</b>  | 362 |
| 4.4.3.7.2  | Bag filters.....   | 363 | 4.4.3.7.2  | <b>Taschenfilter .....</b>  | 364 |
| 4.4.3.7.3  | Packed bed filters .....   | 365 | 4.4.3.7.3  | <b>Schütttschichtfilter.....</b>  | 365 |
| 4.4.3.8    | Absorption.....  | 366 | 4.4.3.8    | <b>Absorption.....</b>  | 366 |
| 4.4.3.8.1  | Packed bed absorber.....   | 368 | 4.4.3.8.1  | <b>Schütttschichtabsorber.....</b>  | 369 |
| 4.4.3.8.2  | Plate absorber.....  | 369 | 4.4.3.8.2  | <b>Prallplattenwäscher.....</b>   | 370 |
| 4.4.3.8.3  | Spray scrubber .....   | 371 | 4.4.3.8.3  | <b>Sprühwäscher .....</b>   | 372 |
| 4.4.3.9    | Carbon adsorption.....   | 372 | 4.4.3.9    | <b>Aktivkohlebehandlung<br/>(Adsorption) .....</b>  | 373 |
| 4.4.3.10   | Biological treatment.....  | 374 | 4.4.3.10   | <b>Biologische Behandlung .....</b>   | 375 |
| 4.4.3.10.1 | Biofilter .....  | 375 | 4.4.3.10.1 | <b>Biofilter.....</b>   | 376 |
| 4.4.3.10.2 | Bioscrubber.....   | 378 | 4.4.3.10.2 | <b>Biowäscher .....</b>   | 379 |
| 4.4.3.11   | Thermal treatment of waste gases.....  | 380 | 4.4.3.11   | <b>Thermische Behandlung von<br/>Abgasen .....</b>  | 381 |
| 4.4.3.11.1 | Thermal oxidation of waste gases.....  | 380 | 4.4.3.11.1 | <b>Thermische Oxidation von<br/>Abgasen .....</b>   | 381 |
| 4.4.3.11.2 | Oxidation of waste gases in an<br>existing boiler.....                         | 386 | 4.4.3.11.2 | <b>Oxidation von Abgasen in einem<br/>schon vorhandenen Kessel.....</b>   | 387 |
| 4.4.3.11.3 | Catalytic oxidation of waste gases.....  | 387 | 4.4.3.11.3 | <b>Katalytische Oxidation von<br/>Abgasen .....</b>   | 388 |
| 4.4.3.12   | Non-thermal plasma treatment.....  | 390 | 4.4.3.12   | <b>Nicht-thermische<br/>Plasmabehandlung .....</b>  | 391 |
| 4.4.3.13   | Physical dispersion of odour/VOC<br>emissions.....                             | 394 | 4.4.3.13   | <b>Verteilung von Geruchs-/VOC-<br/>Emissionen .....</b>  | 395 |
| 4.4.3.13.1 | Extending the height of the<br>discharge stack .....                           | 395 | 4.4.3.13.1 | <b>Vergroößerung der Ableithöhe des<br/>Schornsteins .....</b>  | 396 |
| 4.4.3.13.2 | Increasing stack discharge velocity.....                                       | 396 | 4.4.3.13.2 | <b>Erhöhung der<br/>Austrittsgeschwindigkeit am<br/>Schornstein.....</b>  | 397 |
| 4.5        | End-of-pipe waste water treatment .....  | 396 | 4.5        | <b>Nachsorgende<br/>Abwasserbehandlung (End-of-<br/>pipe-Techniken).....</b>                                    | 397 |
| 4.5.1      | Discharge of waste water from<br>installations .....                           | 397 | 4.5.1      | <b>Abgabe von Abwasser aus<br/>Anlagen.....</b>   | 398 |
| 4.5.1.1    | Waste water treatment techniques<br>applied.....                               | 398 | 4.5.1.1    | <b>Angewendete Techniken der<br/>Abwasserbehandlung .....</b>   | 399 |
| 4.5.2      | Primary treatments .....   | 402 | 4.5.2      | <b>Primärbehandlungen<br/>(Vorbehandlung).....</b>  | 403 |
| 4.5.2.1    | Screening (T1) .....   | 402 | 4.5.2.1    | <b>Rechen/Siebe (T1).....</b>   | 403 |
| 4.5.2.2    | Fat trap for the removal of FOG and<br>light hydrocarbons (T2) .....           | 403 | 4.5.2.2    | <b>Abscheider zur Entfernung<br/>lipophiler Stoffe und<br/>aufschwimmender<br/>Kohlenwasserstoffe (T2).....</b> | 404 |
| 4.5.2.3    | Flow and load equalisation (T3) .....  | 404 | 4.5.2.3    | <b>Vergleichmäßigung von<br/>Durchfluss und Fracht (T3).....</b>  | 405 |
| 4.5.2.4    | Neutralisation (T4) and self-<br>neutralisation.....                           | 405 | 4.5.2.4    | <b>Neutralisation (T4) und<br/>Selbstneutralisation .....</b>   | 406 |
| 4.5.2.5    | Sedimentation (T5) .....   | 406 | 4.5.2.5    | <b>Sedimentation (T5).....</b>  | 407 |

|           |   |     |           |  |     |
|-----------|---|-----|-----------|--|-----|
| 4.5.2.6   | Dissolved air flotation (DAF) (T6).....   | 407 | 4.5.2.6   | <b>Entspannungsflotation (dissolved air flotation, DAF) (T6) .....</b>                                 | 408 |
| 4.5.2.7   | Diversion (emergency) tank (T7) .....   | 408 | 4.5.2.7   | <b>Havariebecken (für Notfälle) (T7) ....</b>  | 409 |
| 4.5.2.8   | Centrifugation (T8).....  | 409 | 4.5.2.8   | <b>Zentrifugation (T8) .....</b>   | 410 |
| 4.5.2.9   | Precipitation (T9) .....  | 409 | 4.5.2.9   | <b>Fällung (T9).....</b>   | 410 |
| 4.5.3     | Secondary treatments .....  | 411 | 4.5.3     | <b>Weitergehende Behandlung des Abwassers .....</b>  | 412 |
| 4.5.3.1   | Aerobic processes .....   | 412 | 4.5.3.1   | <b>Aerobe Verfahren .....</b>  | 413 |
| 4.5.3.1.1 | Activated sludge (T10).....   | 413 | 4.5.3.1.1 | <b>Belebtschlamm (T10).....</b>  | 414 |
| 4.5.3.1.2 | Pure oxygen systems (T11) .....   | 414 | 4.5.3.1.2 | <b>Reinsauerstoffsysteme (T11) .....</b>   | 416 |
| 4.5.3.1.3 | Sequencing batch reactors (SBR) (T12).....  | 415 | 4.5.3.1.3 | <b>SBR-Anlagen (Sequencing Batch Reactors) (T12).....</b>  | 416 |
| 4.5.3.1.4 | Aerobic lagoons (T13).....  | 416 | 4.5.3.1.4 | <b>Aerobe Abwasserteiche (T13) .....</b>   | 417 |
| 4.5.3.1.5 | Trickling filters (T14).....  | 417 | 4.5.3.1.5 | <b>Tropfkörper (T14) .....</b>   | 418 |
| 4.5.3.1.6 | Bio-towers (T15).....   | 417 | 4.5.3.1.6 | <b>Biohochreaktoren23F (T15).....</b>  | 419 |
| 4.5.3.1.7 | Rotating biological contactors (RBC) (T16).....   | 418 | 4.5.3.1.7 | <b>Rotationstauchkörper (T16).....</b>   | 419 |
| 4.5.3.1.8 | Biological aerated flooded filters (BAFF) and submerged biological aerated filters (SBAF) (T17) ..... | 419 | 4.5.3.1.8 | <b>Belüftete und geflutete Biofilter (BAFF) – Getauchte und belüftete Biofilter (SBAF) (T17) .....</b> | 420 |
| 4.5.3.1.9 | High rate and ultrahigh rate aerobic filters (T18) .....  | 419 | 4.5.3.1.9 | <b>Aerobe Schnell- und Ultraschnellfilter (T18).....</b>   | 421 |
| 4.5.3.2   | Anaerobic processes.....  | 420 | 4.5.3.2   | <b>Anaerobe Verfahren .....</b>  | 421 |
| 4.5.3.2.1 | Anaerobic lagoons (T19).....  | 422 | 4.5.3.2.1 | <b>Anaerobe Abwasserteiche (T19) .....</b>   | 423 |
| 4.5.3.2.2 | Anaerobic contact processes (T20).....  | 422 | 4.5.3.2.2 | <b>Anaerobe Kontaktverfahren T(20)...</b>  | 423 |
| 4.5.3.2.3 | Anaerobic filters (T21).....  | 422 | 4.5.3.2.3 | <b>Anaerobfilter (T21).....</b>  | 424 |
| 4.5.3.2.4 | Upflow anaerobic sludge blanket (UASB) (T22) .....  | 423 | 4.5.3.2.4 | <b>UASB-Reaktoren (Upflow anaerobic sludge blanket) (T22) .....</b>                                    | 424 |
| 4.5.3.2.5 | Internal circulation (IC) reactors (T23).....   | 424 | 4.5.3.2.5 | <b>Reaktoren mit interner Zirkulation (T23) .....</b>  | 425 |
| 4.5.3.2.6 | Hybrid USAB reactors (T24) .....  | 424 | 4.5.3.2.6 | <b>Hybrid-UASB-Reaktoren (T24).....</b>  | 426 |
| 4.5.3.2.7 | Fluidised and expanded bed reactors (T25).....  | 424 | 4.5.3.2.7 | <b>Wirbelbett- und Wirbelschicht-Reaktoren (T25) .....</b>   | 426 |
| 4.5.3.2.8 | Expanded granular sludge bed reactors (EGSB) (T26) .....  | 425 | 4.5.3.2.8 | <b>EGSB-Reaktoren (Expanded granular sludge bed reactors) / Hochleistungsreaktoren (T26) .....</b>     | 427 |
| 4.5.3.3   | Aerobic/anaerobic combined processes.....   | 426 | 4.5.3.3   | <b>Kombinierte aerobe und anaerobe Verfahren.....</b>  | 428 |
| 4.5.3.3.1 | Membrane bio-reactors (MBR) (T27).....  | 426 | 4.5.3.3.1 | <b>Membranbioreaktoren (MBR) (T27).....</b>  | 428 |
| 4.5.3.3.2 | Multistage systems (T28).....   | 427 | 4.5.3.3.2 | <b>Mehrstufige Systeme (T28) .....</b>   | 429 |
| 4.5.4     | Tertiary treatments .....   | 428 | 4.5.4     | <b>Nachsorgende Behandlung des Abwassers .....</b>   | 430 |
| 4.5.4.1   | Biological nitrification/denitrification (T29) .....  | 428 | 4.5.4.1   | <b>Biologische Nitrifikation/Denitrifikation (T29) ...</b>   | 430 |
| 4.5.4.2   | Ammonia stripping (T30).....  | 429 | 4.5.4.2   | <b>Ammoniakstrippung (T30) .....</b>   | 431 |
| 4.5.4.3   | Phosphorus removal by biological methods (T31) .....  | 431 | 4.5.4.3   | <b>Biologische Phosphorentfernung (T31) .....</b>  | 433 |
| 4.5.4.4   | Dangerous and priority hazardous substances removal (T32).....  | 432 | 4.5.4.4   | <b>Entfernung gefährlicher und prioritär gefährlicher Stoffe (T32) ...</b>                             | 434 |
| 4.5.4.5   | Filtration (T33).....   | 433 | 4.5.4.5   | <b>Filtration (T33).....</b>   | 435 |
| 4.5.4.6   | Membrane filtration (T34).....  | 433 | 4.5.4.6   | <b>Membranfiltration (T34).....</b>  | 435 |
| 4.5.4.7   | Biological nitrifying filters (T35).....  | 435 | 4.5.4.7   | <b>Biologische nitrifizierende Filter (T35).....</b>   | 437 |
| 4.5.4.8   | Disinfection and sterilisation (T36).....   | 435 | 4.5.4.8   | <b>Desinfektion und Sterilisation (T36).....</b>   | 437 |
| 4.5.4.8.1 | Biocides.....   | 435 | 4.5.4.8.1 | <b>Biozide Stoffe.....</b>   | 437 |
| 4.5.4.8.2 | UV radiation.....   | 436 | 4.5.4.8.2 | <b>UV-Bestrahlung .....</b>  | 438 |
| 4.5.5     | Natural treatments .....  | 437 | 4.5.5     | <b>Natürliche Behandlungen.....</b>  | 439 |
| 4.5.5.1   | Integrated constructed wetlands (ICW) (T37) .....   | 437 | 4.5.5.1   | <b>Integrierte, künstlich geschaffene Feuchtgebiete (ICW) (T37) .....</b>                              | 439 |
| 4.5.6     | Sludge treatment.....   | 438 | 4.5.6     | <b>Klärschlammbehandlung .....</b>   | 441 |

|           |  |     |           |  |     |
|-----------|--|-----|-----------|--|-----|
| 4.5.6.1   | Waste water sludge treatment techniques .....                                  | 439 | 4.5.6.1   | <b>Techniken der Klärschlammbehandlung.....</b>  | 441 |
| 4.5.6.1.1 | Sludge conditioning (T38) .....  | 439 | 4.5.6.1.1 | <b>Schlammkonditionierung (T38) .....</b>  | 441 |
| 4.5.6.1.2 | Sludge stabilisation (T39) .....   | 439 | 4.5.6.1.2 | <b>Schlammstabilisierung (T39).....</b>  | 441 |
| 4.5.6.1.3 | Sludge thickening (T40).....   | 440 | 4.5.6.1.3 | <b>Schlammverdickung (T40).....</b>  | 442 |
| 4.5.6.1.4 | Sludge dewatering (T41).....   | 441 | 4.5.6.1.4 | <b>Schlammwässerung (T41).....</b>   | 443 |
| 4.5.6.1.5 | Sludge drying (T42).....   | 442 | 4.5.6.1.5 | <b>Schlamm Trocknung (T42).....</b>  | 444 |
| 4.5.7     | Waste water treatment in the various sectors .....                             | 442 | 4.5.7     | <b>Abwasserbehandlung in verschiedenen Bereichen.....</b>  | 445 |
| 4.5.7.1   | Meat and poultry .....   | 442 | 4.5.7.1   | <b>Fleisch und Geflügel.....</b>   | 445 |
| 4.5.7.1.1 | Waste water treatment.....   | 442 | 4.5.7.1.1 | <b>Abwasserbehandlung .....</b>  | 445 |
| 4.5.7.2   | Fish and shellfish .....   | 443 | 4.5.7.2   | <b>Fisch und Schalentiere .....</b>  | 446 |
| 4.5.7.2.1 | Waste water characteristics.....   | 443 | 4.5.7.2.1 | <b>Eigenschaften des Abwassers .....</b>   | 446 |
| 4.5.7.2.2 | Waste water treatment.....   | 444 | 4.5.7.2.2 | <b>Abwasserbehandlung .....</b>  | 446 |
| 4.5.7.3   | Fruit and vegetables .....   | 444 | 4.5.7.3   | <b>Obst und Gemüse .....</b>   | 447 |
| 4.5.7.3.1 | Waste water characteristics.....   | 444 | 4.5.7.3.1 | <b>Eigenschaften des Abwassers .....</b>   | 447 |
| 4.5.7.3.2 | Waste water treatment.....   | 445 | 4.5.7.3.2 | <b>Abwasserbehandlung .....</b>  | 448 |
| 4.5.7.3.3 | Water recovery in a vegetable processing company – a case study ....           | 447 | 4.5.7.3.3 | <b>Wasserrückgewinnung in einem gemüseverarbeitenden Betrieb – Fallstudie .....</b>              | 450 |
| 4.5.7.3.4 | Re-use of vegetable washing waste water after treatment – a case study ....    | 449 | 4.5.7.3.4 | <b>Wiederverwendung des Gemüsewaschwassers nach Behandlung – Fallstudie [214H] .....</b>         | 452 |
| 4.5.7.3.5 | Re-use of water during pea processing, after chlorination .....                | 450 | 4.5.7.3.5 | <b>Wiederverwendung des Wassers bei der Verarbeitung von Erbsen nach der Chlorierung .....</b>   | 453 |
| 4.5.7.3.6 | Potato processing .....  | 451 | 4.5.7.3.6 | <b>Kartoffelverarbeitung .....</b>   | 453 |
| 4.5.7.4   | Vegetable oils and fats .....  | 451 | 4.5.7.4   | <b>Pflanzliche Öle und Fette .....</b>   | 454 |
| 4.5.7.4.1 | Waste water treatment.....   | 451 | 4.5.7.4.1 | <b>Abwasserbehandlung .....</b>  | 454 |
| 4.5.7.4.2 | Olive oil .....  | 452 | 4.5.7.4.2 | <b>Olivenöl.....</b>   | 454 |
| 4.5.7.4.3 | Multistage waste water treatment for vegetable oil refining – a case study ... | 453 | 4.5.7.4.3 | <b>Mehrstufige Abwasserbehandlung bei der Raffination pflanzlicher Öle – Fallstudie .....</b>    | 455 |
| 4.5.7.5   | Dairy products.....  | 455 | 4.5.7.5   | <b>Molkereiprodukte.....</b>   | 457 |
| 4.5.7.5.1 | Waste water characteristics.....   | 455 | 4.5.7.5.1 | <b>Eigenschaften des Abwassers .....</b>   | 457 |
| 4.5.7.5.2 | Waste water treatment.....   | 455 | 4.5.7.5.2 | <b>Abwasserbehandlung .....</b>  | 458 |
| 4.5.7.6   | Starch .....   | 456 | 4.5.7.6   | <b>Stärke.....</b>   | 459 |
| 4.5.7.6.1 | Waste water characteristics.....   | 456 | 4.5.7.6.1 | <b>Eigenschaften des Abwassers .....</b>   | 459 |
| 4.5.7.6.2 | Waste water treatment.....   | 456 | 4.5.7.6.2 | <b>Abwasserbehandlung .....</b>  | 459 |
| 4.5.7.6.3 | Re-use of process water in potato starch manufacturing.....                    | 457 | 4.5.7.6.3 | <b>Wiederverwendung von Prozesswasser bei der Kartoffelstärkeherstellung.....</b>                | 460 |
| 4.5.7.7   | Sugar .....  | 460 | 4.5.7.7   | <b>Zucker.....</b>   | 463 |
| 4.5.7.7.1 | Waste water treatment.....   | 460 | 4.5.7.7.1 | <b>Abwasserbehandlung .....</b>  | 463 |
| 4.5.7.8   | Drinks.....  | 463 | 4.5.7.8   | <b>Getränke.....</b>   | 466 |
| 4.5.7.8.1 | Waste water characteristics.....   | 463 | 4.5.7.8.1 | <b>Eigenschaften des Abwassers .....</b>   | 466 |
| 4.5.7.8.2 | Waste water treatment.....   | 463 | 4.5.7.8.2 | <b>Abwasserbehandlung .....</b>  | 466 |
| 4.5.7.8.3 | Brewing.....   | 464 | 4.5.7.8.3 | <b>Brauwirtschaft .....</b>  | 468 |
| 4.5.7.8.4 | Water re-cycling in a brewery.....   | 465 | 4.5.7.8.4 | <b>Wiederverwertung von Wasser in einer Brauerei .....</b>                                       | 468 |
| 4.5.7.8.5 | Distilling .....   | 467 | 4.5.7.8.5 | <b>Destillation (Brennereien).....</b>   | 470 |
| 4.5.7.8.6 | Wine.....  | 468 | 4.5.7.8.6 | <b>Wein.....</b>   | 471 |
| 4.5.7.9   | Citric acid.....   | 469 | 4.5.7.9   | <b>Zitronensäure 30F .....</b>   | 472 |
| 4.6       | Prevention of accidents .....  | 470 | 4.6       | <b>Vermeidung von Betriebsstörungen.....</b>   | 472 |
| 4.6.1     | Identification of potential accidents ....                                     | 470 | 4.6.1     | <b>Typische Betriebsstörungen .....</b>  | 473 |
| 4.6.2     | Risk assessment .....  | 472 | 4.6.2     | <b>Risikobewertung .....</b>   | 475 |
| 4.6.3     | Identify potential accidents which need to be controlled.....                  | 474 | 4.6.3     | <b>Typisierung von potenziellen Betriebsstörungen, die verhindert werden müssen.....</b>         | 476 |
| 4.6.4     | Identify and implement control measures needed .....                           | 474 | 4.6.4     | <b>Identifizierung und Umsetzung der erforderlichen Vorbeuge- und Vermeidungsmaßnahmen .....</b> | 476 |

|           |  |     |           |  |     |
|-----------|--|-----|-----------|--|-----|
| 4.6.5     | Develop, implement and test an emergency plan.....   | 475 | 4.6.5     | <b>Entwicklung, Umsetzung und Tests von Notfallplänen .....</b>  | 478 |
| 4.6.6     | Investigate all accidents and near misses .....  | 477 | 4.6.6     | <b>Untersuchung sämtlicher Betriebsstörungen und Beinahe-Betriebsstörungen .....</b>   | 479 |
| 4.7       | Techniques applicable in some individual sectors.....  | 477 | 4.7       | <b>Techniken, die in bestimmten Einzelbranchen anwendbar sind .....</b>  | 480 |
| 4.7.1     | Meat and poultry .....   | 477 | 4.7.1     | <b>Fleisch und Geflügel .....</b>  | 480 |
| 4.7.1.1   |  |     | 4.7.1.1   | <b>Trennung der anfallenden Stoffe zur Optimierung von Verbrauch, Wiederverwendung, Rückgewinnung, Wiederverwertung und Entsorgung (sowie zur Minimierung von Wasserverbrauch und Abwasserunreinigung) .....</b> | 480 |
|           | Segregation of outputs, to optimise use, re-use, recovery, recycling and disposal (and minimise water use and waste water contamination) ..... | 477 |           | <b>Trockenreinigung.....</b>   | 480 |
| 4.7.1.2   | Dry cleaning .....   | 478 | 4.7.1.2   | <b>Minimierung der Produktion und Verwendung von Scherbeneis.....</b>  | 481 |
| 4.7.1.3   | Minimise the production and use of flake ice .....   | 478 | 4.7.1.3   | <b>Fisch und Schalentiere.....</b>   | 481 |
| 4.7.2     | Fish and shellfish.....  | 478 | 4.7.2     | <b>Trennung der anfallenden Stoffe zur Optimierung von Verbrauch, Wiederverwendung, Rückgewinnung, Wiederverwertung und Entsorgung (sowie zur Minimierung von Wasserverbrauch und Abwasserunreinigung) .....</b> | 481 |
| 4.7.2.1   |  |     | 4.7.2.1   | <b>Trockenreinigung.....</b>   | 481 |
|           | Segregation of outputs, to optimise use, re-use, recovery, recycling and disposal (and minimise water use and waste water contamination) ..... | 478 |           | <b>Ausschließliche Verwertung von qualitativ hochwertigem Fisch.....</b>   | 482 |
| 4.7.2.2   | Dry cleaning .....   | 479 | 4.7.2.2   | <b>Abtransport von Haut und Fett aus der Enthäutungstrommel mittels Vakuum .....</b>   | 482 |
| 4.7.2.3   | Use only high quality fish.....  | 479 | 4.7.2.3   | <b>Entfernung und Abtransport des Fettes und der Eingeweide durch Absaugung .....</b>  | 483 |
| 4.7.2.4   | Transport of skin and fat from the skinner drum by vacuum .....  | 480 | 4.7.2.4   | <b>Trockener Transport von Fett, Eingeweiden, Haut und Filets mittels feinmaschiger Förderbänder .....</b>   | 483 |
| 4.7.2.5   | Removal and transport of fat and viscera by vacuum .....   | 480 | 4.7.2.5   | <b>Vermeidung des Entschuppens, wenn der Fisch anschließend noch enthäutet wird .....</b>  | 485 |
| 4.7.2.6   | Dry transport of fat, viscera, skin and fillets, incorporating mesh conveyors .....  | 481 | 4.7.2.6   | <b>Verwendung des filtrierten, rückgeführten Abwassers vom Entschuppen für das Vorspülen von Fischen .....</b>   | 485 |
| 4.7.2.7   | Avoiding scaling if the fish is subsequently skinned.....  | 482 | 4.7.2.7   | <b>Fallstudien .....</b>   | 485 |
| 4.7.2.8   | Using the filtered recirculated scaling waste water for preliminary fish rinsing.....  | 482 | 4.7.2.8   | <b>Heringsverarbeitung in Dänemark ..</b>  | 485 |
| 4.7.2.9   | Case studies .....   | 483 | 4.7.2.9   | <b>Fischverarbeitung im Vereinigten Königreich .....</b>   | 486 |
| 4.7.2.9.1 | Herring processing in Denmark.....   | 483 | 4.7.2.9.1 | <b>Obst und Gemüse.....</b>  | 487 |
| 4.7.2.9.2 | Fish processing in the UK .....  | 484 | 4.7.2.9.2 | <b>Trennung der anfallenden Stoffe zur Optimierung von Verbrauch, Wiederverwendung, Rückgewinnung, Wiederverwertung und Entsorgung (sowie zur Minimierung von Wasserverbrauch und Abwasserunreinigung).....</b>  | 487 |
| 4.7.3     | Fruit and vegetables.....  | 485 | 4.7.3     |  |     |
| 4.7.3.1   |  |     | 4.7.3.1   |  |     |
|           | Segregation of outputs, to optimise use, re-use, recovery, recycling and disposal (and minimise water use and waste water contamination) ..... | 485 |           |  |     |

|           |  |     |           |  |     |
|-----------|--|-----|-----------|--|-----|
| 4.7.3.2   | Dry cleaning.....  | 485 | 4.7.3.2   | <b>Trockenreinigung .....</b>  | 488 |
| 4.7.3.3   | Protected outdoor storage of fruit and vegetables.....   | 485 | 4.7.3.3   | <b>Geschützte Freiluftlagerung von Obst und Gemüse .....</b>   | 488 |
| 4.7.3.4   | Peeling of fruit and vegetables.....   | 486 | 4.7.3.4   | <b>Schälen von Obst und Gemüse .....</b>   | 488 |
| 4.7.3.4.1 | Steam peeling – continuous process....   | 486 | 4.7.3.4.1 | <b>Dampfschälung – kontinuierlicher Prozess .....</b>  | 489 |
| 4.7.3.4.2 | Steam peeling – batch process .....  | 487 | 4.7.3.4.2 | <b>Dampfschälung – Chargenbetrieb ...</b>  | 490 |
| 4.7.3.4.3 | Abrasion peeling .....   | 488 | 4.7.3.4.3 | <b>Abriebschälung.....</b>   | 491 |
| 4.7.3.4.4 | Knife peeling.....   | 489 | 4.7.3.4.4 | <b>Messerschälung.....</b>   | 492 |
| 4.7.3.4.5 | Wet caustic peeling .....  | 491 | 4.7.3.4.5 | <b>Nasse Laugenschälung .....</b>  | 493 |
| 4.7.3.4.6 | Dry caustic peeling.....   | 492 | 4.7.3.4.6 | <b>Trockene Laugenschälung .....</b>   | 495 |
| 4.7.3.4.7 | Flame peeling .....  | 493 | 4.7.3.4.7 | <b>Flammenschälung.....</b>  | 496 |
| 4.7.3.5   | Blanching of fruit and vegetables .....  | 493 | 4.7.3.5   | <b>Blanchieren von Obst und Gemüse .....</b>   | 496 |
| 4.7.3.5.1 | Steam blanching with air cooling.....  | 494 | 4.7.3.5.1 | <b>Dampfblanchieren mit Luftkühlung .....</b>  | 496 |
| 4.7.3.5.2 | Belt blanching with water cooling .....  | 494 | 4.7.3.5.2 | <b>Förderbandblanchieren mit Wasserkühlung .....</b>   | 497 |
| 4.7.3.5.3 | Belt blanching with air cooling .....  | 495 | 4.7.3.5.3 | <b>Förderbandblanchieren mit Luftkühlung .....</b>   | 498 |
| 4.7.3.5.4 | Drum blancher with countercurrent water cooling.....   | 496 | 4.7.3.5.4 | <b>Trommelblanchieren mit Gegenstrom-Wasserkühlung .....</b>   | 499 |
| 4.7.3.6   | Cooling fruit and vegetables before freezing .....   | 497 | 4.7.3.6   | <b>Kühlung von Obst und Gemüse vor dem Tiefkühlen .....</b>  | 500 |
| 4.7.3.7   | Re-use of water in fruit and vegetable processing .....  | 499 | 4.7.3.7   | <b>Wiederverwendung von Wasser bei der Obst- und Gemüseverarbeitung .....</b>                                    | 502 |
| 4.7.4     | Vegetable oils and fats .....  | 501 | 4.7.4     | <b>Pflanzliche Öle und Fette .....</b>   | 504 |
| 4.7.4.1   | Two-phase extraction of olive oil .....  | 501 | 4.7.4.1   | <b>Zweiphasenextraktion von Olivenöl.....</b>  | 504 |
| 4.7.4.2   | Countercurrent flow desolventiser-toaster (DT) in vegetable oil extraction.....                  | 504 | 4.7.4.2   | <b>Im Gegenstromverfahren arbeitende Desolventierer-Toaster (DT) bei der Extraktion pflanzlicher Öle.....</b>    | 507 |
| 4.7.4.3   | Re-use of the vapours from the DT in the miscella distillation in vegetable oil extraction ..... | 506 | 4.7.4.3   | <b>Wiederverwendung des DT-Brüdens im Miscella-Destillationssystem bei der Extraktion pflanzlicher Öle .....</b> | 509 |
| 4.7.4.4   | Re-use of heat in the hardening of vegetable oils .....  | 507 | 4.7.4.4   | <b>Wiederverwendung von Wärme bei der Härtung pflanzlicher Öle .....</b>   | 510 |
| 4.7.4.5   | Mineral oil scrubber to recover hexane .....   | 508 | 4.7.4.5   | <b>Mineralölwäscher zur Rückgewinnung von Hexan .....</b>  | 510 |
| 4.7.4.6   | Hexane recovery using a reboiler and gravity separator.....                                      | 509 | 4.7.4.6   | <b>Hexanrückgewinnung mit einem Auskocher und einem Schwerkraftabscheider .....</b>                              | 512 |
| 4.7.4.7   | Refining of vegetable oils .....   | 510 | 4.7.4.7   | <b>Raffination pflanzlicher Öle .....</b>  | 513 |
| 4.7.4.7.1 | Chemical refining.....   | 510 | 4.7.4.7.1 | <b>Chemische Raffination .....</b>   | 513 |
| 4.7.4.7.2 | Physical refining .....  | 512 | 4.7.4.7.2 | <b>Physikalische Raffination.....</b>  | 515 |
| 4.7.4.8   | Using citric acid instead of phosphoric acid for acid degumming..                                | 513 | 4.7.4.8   | <b>Verwendung von Zitronensäure an Stelle von Phosphorsäure für die Ölentschleimung .....</b>                    | 516 |
| 4.7.4.9   | Enzymatic degumming .....  | 514 | 4.7.4.9   | <b>Enzymatische Entschleimung .....</b>  | 517 |
| 4.7.4.10  | The use of cyclones to reduce wet dust emissions in vegetable oil extraction.....                | 516 | 4.7.4.10  | <b>Einsatz von Zyklonen zur Verringerung der Nasstaubemissionen bei der Extraktion pflanzlicher Öle .....</b>    | 519 |
| 4.7.4.11  | Water ring pumps for generating an auxiliary vacuum of 40 to 120 mbar ...                        | 517 | 4.7.4.11  | <b>Wasserringpumpen zur Erzeugung eines zusätzlichen Vakuums von 40 – 120 mbar .....</b>                         | 520 |
| 4.7.4.12  | Deodorisation.....   | 517 | 4.7.4.12  | <b>Desodorierung (Dämpfung) .....</b>  | 520 |

|            |  |     |            |   |     |
|------------|--|-----|------------|---|-----|
| 4.7.4.12.1 | Double scrubber in combination with a once-through cooling system in vegetable oil deodorisation.....  | 518 | 4.7.4.12.1 | <b>Doppelwäscher in Kombination mit einem Durchlaufkühlssystem bei der Desodorierung von pflanzlichen Ölen .....</b>  | 521 |
| 4.7.4.12.2 |  |     | 4.7.4.12.2 | <b>Einzelner Wäscher in Kombination mit einem geschlossenen alkalischen Kreislauf bei der Desodorierung von pflanzlichen Ölen .....</b>   | 523 |
| 4.7.4.12.3 | Single scrubber in combination with an alkaline closed-circuit system in vegetable oil deodorisation.....                                      | 520 | 4.7.4.12.3 | <b>Einzelner Wäscher in Kombination mit Trockenkondensation bei der Desodorierung von pflanzlichen Ölen .....</b>   | 525 |
| 4.7.5      | Dairy products .....   | 524 | 4.7.5      | <b>Molkereiprodukte .....</b>   | 526 |
| 4.7.5.1    |  |     | 4.7.5.1    | <b>Trennung der anfallenden Stoffe zur Optimierung der Verwendung, Wiederverwendung, Wiederverwertung und Entsorgung (und Minimierung des Wasserverbrauchs und der Abwasserkontamination) .....</b> | 526 |
| 4.7.5.2    | Segregation of outputs, to optimise use, re-use, recovery, recycling and disposal (and minimise water use and waste water contamination) ..... | 524 | 4.7.5.2    | <b>Trockenreinigung.....</b>  | 527 |
| 4.7.5.3    | Dry cleaning .....   | 524 | 4.7.5.3    | <b>Teilmohogenisierung der Marktmilch.....</b>  | 527 |
| 4.7.5.4    | Partial homogenisation of market milk .....  | 525 | 4.7.5.4    | <b>Steuerung von Milchtransport, Pasteurisation, Homogenisierung und CIP-Reinigung per Computer...</b>  | 528 |
| 4.7.5.5    | Use of computer controlled milk transfer, pasteurisation, homogenisation and CIP equipment....   | 525 | 4.7.5.5    | <b>Einsatz kontinuierlich arbeitender Pasteurisatoren.....</b>  | 530 |
| 4.7.5.6    | Use of continuous pasteurisers .....   | 527 | 4.7.5.6    | <b>Einsatz regenerativer Wärmetauschverfahren bei der Pasteurisation .....</b>  | 530 |
| 4.7.5.7    | Regenerative heat-exchange in a pasteurisation process.....  | 527 | 4.7.5.7    | <b>Verringerung der Reinigungsanforderungen bei Zentrifugen durch bessere Vorfiltration und Klärung der Milch .....</b>   | 531 |
| 4.7.5.8    | Reduce cleaning requirements of centrifuges by improved preliminary milk filtration and clarification.....                                     | 528 | 4.7.5.8    | <b>Zweistufiges Trocknungsverfahren bei der Herstellung von Milchpulver .....</b>   | 532 |
| 4.7.5.9    | Two-stage drying in milk powder production.....  | 529 | 4.7.5.9    | <b>Einsatz eines aseptischen Verpackungssystems ohne die Notwendigkeit einer Aseptikkammer.....</b>   | 533 |
| 4.7.5.10   | Use of an aseptic packaging system not requiring an aseptic chamber.....   | 530 | 4.7.5.10   | <b>Automatische Erkennung des Übergangs zwischen Produkt- und Wasserphasen.....</b>   | 535 |
| 4.7.5.11   | Online detection of transition points between the product and the water phases .....   | 532 | 4.7.5.11   | <b>Einbau von Lagertanks in der Produktionslinie zur Minimierung der Produktumwälzung in den Pasteurisatoren.....</b>   | 535 |
| 4.7.5.12   | Provision of in-line storage tanks to minimise product recirculation in pasteurisers .....   | 532 | 4.7.5.12   | <b>„Komponentenabfüllung“ mit bedarfssynchroner Mischung.....</b>   | 536 |
| 4.7.5.13   | Just-in-time mixing “component filling” .....  | 533 | 4.7.5.13   | <b>Butter .....</b>   | 537 |
| 4.7.5.13.1 | Butter .....   | 534 | 4.7.5.13.1 | <b>Minimierung der Verluste in der Butterherstellung .....</b>  | 537 |
| 4.7.5.14   | Minimisation of losses during buttermaking.....  | 534 | 4.7.5.14   | <b>Käse.....</b>  | 537 |
| 4.7.5.14.1 | Cheese .....   | 534 | 4.7.5.14.1 | <b>Standardisierung des Proteins in der Käsereimilch durch Ultrafiltration (UF) .....</b>   | 537 |
| 4.7.5.14.2 | Using ultrafiltration (UF) for protein standardisation of cheese milk.....   | 534 | 4.7.5.14.2 | <b>Verringerung der Fett- und Käsefeinanteile in der Molke .....</b>  | 538 |
| 4.7.5.14.2 | Reduction of fat and cheese fines in whey .....  | 535 |            |   |     |

|            |  |     |            |  |     |
|------------|--|-----|------------|--|-----|
| 4.7.5.14.3 | Minimise the production of acid whey and its discharge to the WWTP .....                               | 536 | 4.7.5.14.3 | <b>Minimierung der Produktion von Sauermolke und ihrer Abgabe in die Kläranlage.....</b>                         | 539 |
| 4.7.5.14.4 | Recovery and use of whey .....   | 536 | 4.7.5.14.4 | <b>Rückgewinnung und Verwendung von Molke.....</b>   | 539 |
| 4.7.5.14.5 | Recovery of salt whey by evaporation.....  | 537 | 4.7.5.14.5 | <b>Rückgewinnung der Sauermolke durch Verdampfung.....</b>   | 540 |
| 4.7.5.14.6 | Recovery of whey by removal of salt using RO.....  | 537 | 4.7.5.14.6 | <b>Rückgewinnung von Molke durch Salzentzug mittels Umkehrosmose...</b>  | 540 |
| 4.7.5.14.7 | Utilisation of heat from warm whey for preheating cheese milk .....                                    | 537 | 4.7.5.14.7 | <b>Nutzung der in der warmen Molke enthaltenen Wärmeenergie für die Vorwärmung von Käseemilch .....</b>          | 541 |
| 4.7.5.14.8 | High temperature cheese ripening with later humidification and ionisation of the ventilation air ..... | 538 | 4.7.5.14.8 | <b>Käseerifung bei hohen Temperaturen mit späterer Befeuchtung und Ionisierung der zirkulierenden Luft .....</b> | 541 |
| 4.7.5.15   | Ice-cream.....   | 539 | 4.7.5.15   | <b>Speiseeis.....</b>  | 542 |
| 4.7.5.15.1 | Heat recovery from pasteurisation in ice-cream production.....   | 539 | 4.7.5.15.1 | <b>Wärmerückgewinnung aus der Pasteurisation bei der Herstellung von Speiseeis.....</b>                          | 542 |
| 4.7.5.16   | Re-use and recycling of water for cleaning in dairies .....  | 540 | 4.7.5.16   | <b>Wiederverwendung und Wiederverwertung von Wasser zur Reinigung in Molkereien .....</b>                        | 543 |
| 4.7.5.17   | Re-using warm cooling water for cleaning.....  | 541 | 4.7.5.17   | <b>Wiederverwendung von warmem Kühlwasser zur Reinigung.....</b>   | 544 |
| 4.7.5.18   | In-process environmental management at a dairy – a case study.....                                     | 542 | 4.7.5.18   | <b>Prozessintegriertes Umweltmanagement in einer Molkerei – Fallstudie.....</b>                                  | 545 |
| 4.7.6      | Starch .....   | 543 | 4.7.6      | <b>Stärke.....</b>   | 546 |
| 4.7.6.1    | Countercurrent water use/re-use in starch washing.....   | 543 | 4.7.6.1    | <b>Verwendung/Wiederverwendung von Stärkewaschwasser im Gegenstrom .....</b>                                     | 546 |
| 4.7.7      | Sugar .....  | 544 | 4.7.7      | <b>Zucker.....</b>   | 547 |
| 4.7.7.1    | Drying of sugar beet pulp.....   | 544 | 4.7.7.1    | <b>Trocknung der Zuckerrübenschnitzel.....</b>   | 547 |
| 4.7.7.1.1  | Low temperature drying of sugar beet pulp.....   | 544 | 4.7.7.1.1  | <b>Niedertemperaturtrocknung von Zuckerrübenschnitzeln .....</b>   | 547 |
| 4.7.7.1.2  | High temperature drying of sugar beet pulp.....  | 545 | 4.7.7.1.2  | <b>Hochtemperaturtrocknung von Zuckerrübenschnitzeln .....</b>   | 548 |
| 4.7.7.1.3  | Two-stage drying of sugar beet pulp...   | 547 | 4.7.7.1.3  | <b>Zweistufentrocknung der Zuckerrübenschnitzel.....</b>   | 550 |
| 4.7.7.1.4  | Steam drying of sugar beet pulp.....   | 547 | 4.7.7.1.4  | <b>Verdampfungstrocknung von Zuckerrübenschnitzeln .....</b>   | 551 |
| 4.7.7.1.5  | Comparison of steam, HTD and two-stage drying of beet pulp.....  | 548 | 4.7.7.1.5  | <b>Vergleich zwischen Verdampfungs-, Hochtemperatur- und Zweistufentrocknung von Zuckerrübenschnitzeln .....</b> | 552 |
| 4.7.7.2    | Reducing sugar beet soil tare .....  | 556 | 4.7.7.2    | <b>Verringerung des Erdanteils bei den Zuckerrüben .....</b>   | 560 |
| 4.7.7.3    | Sugar beet water/waste water re-use ...  | 557 | 4.7.7.3    | <b>Wiederverwendung des Rübenwaschwassers bzw. -abwassers .....</b>  | 561 |
| 4.7.8      | Coffee.....  | 558 | 4.7.8      | <b>Kaffee.....</b>   | 562 |
| 4.7.8.1    | Waste heat re-use in instant coffee manufacturing .....  | 558 | 4.7.8.1    | <b>Abwärmennutzung bei der Herstellung von Instantkaffee .....</b>   | 562 |
| 4.7.8.2    | Abatement of air emissions from agglomeration during instant coffee manufacturing .....                | 558 | 4.7.8.2    | <b>Vermeidung von Luftemissionen aus der Agglomerationsstufe bei der Herstellung von Instantkaffee....</b>       | 562 |
| 4.7.8.3    | Biofilter – used in coffee processing...   | 559 | 4.7.8.3    | <b>Nutzung von Biofiltern in der Kaffeeverarbeitung.....</b>   | 562 |
| 4.7.8.4    | Coffee roasting.....   | 559 | 4.7.8.4    | <b>Kaffeeröstung .....</b>   | 563 |
| 4.7.8.4.1  | Recirculation of air during coffee roasting.....   | 561 | 4.7.8.4.1  | <b>Kaffeeröstung im Umluftbetrieb .....</b>  | 565 |

|           |  |     |           |   |     |
|-----------|--|-----|-----------|---|-----|
| 4.7.8.4.2 | Water mist cooling of roasted coffee...  | 562 | 4.7.8.4.2 | <b>Wassernebelkühlung von Röstkaffee</b> .....  | 566 |
| 4.7.8.4.3 | Coffee roasting followed by catalytic oxidation of the waste gases .....   | 563 | 4.7.8.4.3 | <b>Kaffeeröstung mit nachfolgender katalytischer Oxidation der Abgase</b> .....   | 567 |
| 4.7.8.4.4 | Biofilter – used in coffee processing ...  | 565 | 4.7.8.4.4 | <b>Nutzung von Biofiltern in der Kaffeeverarbeitung</b> 35F .....   | 569 |
| 4.7.9     | Drinks .....   | 566 | 4.7.9     | <b>Getränke</b> .....   | 569 |
| 4.7.9.1   | Segregation of outputs, to optimise use, re-use, recovery, recycling and disposal (and minimise water use and waste water contamination) ..... | 566 | 4.7.9.1   | <b>Trennung der anfallenden Stoffe zur Optimierung der Verwendung, Wiederverwendung, Wiederverwertung und Entsorgung (und Minimierung des Wasserverbrauchs und der Abwasserkontamination)</b> ..... | 569 |
| 4.7.9.2   | Dry cleaning .....   | 566 | 4.7.9.2   | <b>Trockenreinigung</b> .....   | 570 |
| 4.7.9.3   | Recovery of yeast after fermentation...  | 566 | 4.7.9.3   | <b>Rückgewinnung der Hefe nach der Fermentation</b> .....   | 570 |
| 4.7.9.4   | Filtration .....   | 567 | 4.7.9.4   | <b>Filtration</b> .....   | 571 |
| 4.7.9.4.1 | Filtration of the product using membrane separation.....   | 567 | 4.7.9.4.1 | <b>Membranfiltration des Produktes</b> ....   | 571 |
| 4.7.9.4.2 | Cross-flow filtration .....  | 568 | 4.7.9.4.2 | <b>Cross-Flow-Filtration</b> .....  | 571 |
| 4.7.9.4.3 | Recovery of filter material when the product is filtered using natural mineral adsorbents.....   | 569 | 4.7.9.4.3 | <b>Rückgewinnung von Filtermaterial, wenn das Produkt durch natürliche mineralische Adsorptionsmaterialien gefiltert wird</b> .....   | 572 |
| 4.7.9.5   | Bottling.....  | 569 | 4.7.9.5   | <b>Abfüllung in Flaschen</b> .....  | 573 |
| 4.7.9.5.1 | Integrated bottling installation.....  | 569 | 4.7.9.5.1 | <b>Integrierte Abfüllanlage</b> .....   | 573 |
| 4.7.9.5.2 | Multistage bottle cleaning system .....  | 573 | 4.7.9.5.2 | <b>Mehrstufige Flaschenreinigung</b> .....  | 577 |
| 4.7.9.5.3 | Re-use of bottle cleaning solutions after sedimentation and filtration.....  | 576 | 4.7.9.5.3 | <b>Wiederverwendung der Reinigungslösungen aus der Flaschenreinigung nach Sedimentation und Filtration</b> .....  | 580 |
| 4.7.9.5.4 | Optimisation of water consumption in bottle cleaning .....   | 577 | 4.7.9.5.4 | <b>Optimierung des Wasserverbrauchs bei der Flaschenreinigung</b> .....   | 581 |
| 4.7.9.5.5 | Re-use of bottle pasteurising water .....  | 577 | 4.7.9.5.5 | <b>Wiederverwendung des Wassers aus der Flaschenpasteurisation</b> .....  | 581 |
| 4.7.9.6   | Brewing .....  | 578 | 4.7.9.6   | <b>Brauwirtschaft</b> .....   | 582 |
| 4.7.9.6.1 | Mashing.....   | 580 | 4.7.9.6.1 | <b>Maischen</b> .....   | 585 |
| 4.7.9.6.2 | Mash infusion process .....  | 580 | 4.7.9.6.2 | <b>Maischen nach dem Infusionsverfahren</b> .....   | 585 |
| 4.7.9.6.3 | Mash decoction process.....  | 581 | 4.7.9.6.3 | <b>Maischen nach dem Dekoktionsverfahren</b> .....  | 586 |
| 4.7.9.6.4 | Re-use of hot water from wort cooling.....   | 581 | 4.7.9.6.4 | <b>Wiederverwendung des Heißwassers aus der Würzekühlung</b> .....  | 586 |
| 4.7.9.6.5 | Heat recovery from wort boiling .....  | 582 | 4.7.9.6.5 | <b>Wärmerückgewinnung aus der Würzekochung</b> .....  | 587 |
| 4.7.9.6.6 | Process optimisation in a small brewery – a case study .....   | 583 | 4.7.9.6.6 | <b>Prozessoptimierung in einer kleinen Brauerei – eine Fallstudie</b> ....  | 588 |
| 4.7.9.7   | Distilling.....  | 584 | 4.7.9.7   | <b>Destillation</b> .....   | 589 |
| 4.7.9.7.1 | Recovery of distiller’s dried grains with solubles (DDGS) .....  | 584 | 4.7.9.7.1 | <b>Rückgewinnung von festen und gelösten Stoffen aus der Destillation (distiller’s dried grains with solubles, DDGS)</b> .....  | 589 |
| 4.7.9.7.2 | Concentration of mash from molasses distilling .....   | 585 | 4.7.9.7.2 | <b>Konzentration der Schlempe aus der Melassedestillation</b> .....   | 590 |
| 4.7.9.8   | Wine .....   | 586 | 4.7.9.8   | <b>Wein</b> .....   | 591 |
| 4.7.9.8.1 | Re-use of cleaning solution from the cold stabilisation tanks .....  | 586 | 4.7.9.8.1 | <b>Wiederverwendung der Reinigungslösung aus den Kaltstabilisationstanks</b> .....  | 591 |

|           |  |     |           |   |     |
|-----------|--|-----|-----------|---|-----|
| 4.7.9.8.2 | Gradual discharge of cleaning solution from the cold stabilisation tanks to the WWTP.....      | 586 | 4.7.9.8.2 | <b>Allmähliche Ableitung der Reinigungslösung aus den Kaltstabilisationstanks in die Kläranlage.....</b>                              | 592 |
| 5         | BEST AVAILABLE TECHNIQUES .....  | 589 | 5         | <b>BESTE VERFÜGBARE TECHNIKEN.....</b>  | 593 |
| 5.1       | General BAT for the whole FDM sector.....  | 592 | 5.1       | <b>Allgemeine BVT für den gesamten Bereich der Nahrungsmittelproduktion .....</b>   | 596 |
| 5.1.1     | Environmental management.....  | 594 | 5.1.1     | <b>Umweltmanagement.....</b>  | 598 |
| 5.1.2     | Collaboration with upstream and downstream activities.....                                     | 595 | 5.1.2     | <b>Zusammenarbeit mit vor- und nachgelagerten Tätigkeiten.....</b>  | 599 |
| 5.1.3     | Equipment and installation cleaning ...  | 595 | 5.1.3     | <b>Reinigung von Anlagen und Geräten.....</b>   | 599 |
| 5.1.4     | Additional BAT for some processes and unit operations applied in a number of FDM sectors ..... | 596 | 5.1.4     | <b>Zusätzliche BVT für Prozesse und Arbeitsverfahren, die in mehreren Branchen der Nahrungsmittelindustrie eingesetzt werden.....</b> | 600 |
| 5.1.4.1   | Materials reception/despatch.....  | 596 | 5.1.4.1   | <b>Warenannahme/ -abfertigung .....</b>   | 600 |
| 5.1.4.2   | Centrifugation/separation.....   | 596 | 5.1.4.2   | <b>Zentrifugation/Separation .....</b>  | 600 |
| 5.1.4.3   | Smoking.....   | 596 | 5.1.4.3   | <b>Räucherei .....</b>  | 600 |
| 5.1.4.4   | Frying.....  | 596 | 5.1.4.4   | <b>Frittieren .....</b>   | 600 |
| 5.1.4.5   | Preservation in cans, bottles and jars ..  | 596 | 5.1.4.5   | <b>Konservierung in Dosen, Flaschen und Gläsern.....</b>  | 600 |
| 5.1.4.6   | Evaporation.....   | 596 | 5.1.4.6   | <b>Verdampfung .....</b>  | 601 |
| 5.1.4.7   | Freezing and refrigeration.....  | 597 | 5.1.4.7   | <b>Gefrieren und Kühlen .....</b>   | 601 |
| 5.1.4.8   | Cooling.....   | 597 | 5.1.4.8   | <b>Kühlung.....</b>   | 601 |
| 5.1.4.9   | Packing.....   | 597 | 5.1.4.9   | <b>Verpacken .....</b>  | 601 |
| 5.1.4.10  | Energy generation and use .....  | 598 | 5.1.4.10  | <b>Erzeugung und Verwendung von Energie.....</b>  | 602 |
| 5.1.4.11  | Water use .....  | 598 | 5.1.4.11  | <b>Verwendung von Wasser .....</b>  | 602 |
| 5.1.4.12  | Compressed air systems .....   | 598 | 5.1.4.12  | <b>Druckluftsysteme.....</b>  | 602 |
| 5.1.4.13  | Steam systems.....   | 598 | 5.1.4.13  | <b>Dampfsysteme.....</b>  | 602 |
| 5.1.5     | Minimisation of air emissions.....   | 598 | 5.1.5     | <b>Verminderung von Abluftemissionen .....</b>  | 602 |
| 5.1.6     | Waste water treatment.....   | 599 | 5.1.6     | <b>Abwasserbehandlung .....</b>   | 603 |
| 5.1.7     | Accidental releases.....   | 601 | 5.1.7     | <b>Unbeabsichtigte Freisetzen.....</b>  | 605 |
| 5.2       | Additional BAT for some individual FDM sectors.....  | 601 | 5.2       | <b>Zusätzliche BVT für einzelne Branchen der Nahrungsmittelproduktion .....</b>   | 605 |
| 5.2.1     | Additional BAT for the meat and poultry sector .....   | 601 | 5.2.1     | <b>Zusätzliche BVT für den Sektor Fleisch und Geflügel.....</b>   | 605 |
| 5.2.2     | Additional BAT for the fish and shellfish sector .....   | 601 | 5.2.2     | <b>Zusätzliche BVT für den Sektor Fisch und Schalentiere .....</b>  | 605 |
| 5.2.3     | Additional BAT for the fruit and vegetables sector .....                                       | 602 | 5.2.3     | <b>Zusätzliche BVT für den Sektor Obst und Gemüse .....</b>   | 606 |
| 5.2.4     | Additional BAT for the vegetable oils and fats sector.....                                     | 603 | 5.2.4     | <b>Zusätzliche BVT für die Gewinnung und Verarbeitung pflanzlicher Öle und Fette .....</b>  | 607 |
| 5.2.5     | Additional BAT for dairies .....   | 603 | 5.2.5     | <b>Zusätzliche BVT für Molkereien.....</b>  | 607 |
| 5.2.5.1   | Additional BAT for the production of market milk.....  | 604 | 5.2.5.1   | <b>Zusätzliche BVT für die Produktion von Marktmilch.....</b>   | 608 |
| 5.2.5.2   | Additional BAT for milk powder production .....  | 604 | 5.2.5.2   | <b>Zusätzliche BVT für die Produktion von Milchpulver .....</b>   | 608 |
| 5.2.5.3   | Additional BAT for buttermaking.....   | 605 | 5.2.5.3   | <b>Zusätzliche BVT für die Herstellung von Butter.....</b>  | 609 |
| 5.2.5.4   | Additional BAT for cheesemaking .....  | 605 | 5.2.5.4   | <b>Zusätzliche BVT für die Herstellung von Käse.....</b>  | 609 |
| 5.2.5.5   | Additional BAT for ice-cream manufacturing .....   | 605 | 5.2.5.5   | <b>Zusätzliche BVT für die Produktion von Speiseeis .....</b>   | 609 |
| 5.2.6     | Additional BAT for starch manufacturing .....  | 605 | 5.2.6     | <b>Zusätzliche BVT für die Stärkeproduktion .....</b>   | 609 |

|         |  |     |         |  |     |
|---------|--|-----|---------|--|-----|
| 5.2.7   | Additional BAT for the sugar sector ...  | 606 | 5.2.7   | <b>Zusätzliche BVT für den Zuckersektor .....</b>                    | 610 |
| 5.2.8   | Additional BAT for the coffee sector ..  | 606 | 5.2.8   | <b>Zusätzliche BVT für den Kaffeesektor .....</b>                    | 610 |
| 5.2.9   | Additional BAT for drinks manufacturing.....   | 606 | 5.2.9   | <b>Zusätzliche BVT für die Getränkeproduktion .....</b>              | 610 |
| 5.2.9.1 | Additional BAT for brewing .....   | 607 | 5.2.9.1 | <b>Zusätzliche BVT für Brauereien .....</b>                          | 611 |
| 5.2.9.2 | Additional BAT for winemaking.....   | 607 | 5.2.9.2 | <b>Zusätzliche BVT für die Weinherstellung .....</b>                 | 611 |
| 6       | <b>EMERGING TECHNIQUES.....</b>  | 609 | 6       | <b>NEU AUFTRETENDE TECHNIKEN.....</b>                                | 613 |
| 6.1     | <b>Use of UV/ozone in absorption for odour abatement.....</b>                                | 609 | 6.1     | Einsatz von UV/Ozon zur Absorption bei der Geruchsminderung .....    | 613 |
| 7       | <b>CONCLUDING REMARKS .....</b>  | 611 | 7       | <b>SCHLUSSBEMERKUNGEN .....</b>                                      | 615 |
| 7.1     | <b>Timing of the work .....</b>  | 611 | 7.1     | Zeitlicher Ablauf der Arbeit.....                                    | 615 |
| 7.2     | <b>Level of consensus, driving forces and issues arising from the final TWG meeting.....</b> | 611 | 7.2     | Konsensniveau, Anlässe und Fragen vom Abschlusstreffen der TWG ..... | 615 |
| 7.3     | <b>Information provided.....</b>   | 612 | 7.3     | Mitgeteilte Informationen .....                                      | 616 |
| 7.4     | <b>Information imbalances and gaps....</b>   | 614 | 7.4     | Informationsungleichgewicht und -lücken .....                        | 618 |
| 7.5     | <b>Recommendations for future work..</b>   | 615 | 7.5     | Empfehlungen für zukünftige Arbeiten .....                           | 619 |
| 7.6     | <b>Suggested topics for future R&amp;D projects .....</b>                                    | 617 | 7.6     | Themenvorschläge für zukünftige F&E-Projekte .....                   | 621 |
| 8       | <b>REFERENCES .....</b>  | 619 | 8       | <b>LITERATUR .....</b>   | 623 |
|         | <b>GLOSSARY .....</b>  | 629 |         | <b>GLOSSAR .....</b>   | 643 |

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## List of figures

|  |     |
|--|-----|
| Figure 2.1: Flow diagram of continuous neutralisation of oils and fats.....  | 23  |
| Figure 2.2: An example of the steeping procedure .....   | 26  |
| Figure 2.3: Canned meat production.....  | 62  |
| Figure 2.4: Cooked ham and shoulder production.....  | 64  |
| Figure 2.5: Cured ham production.....  | 66  |
| Figure 2.6: The process for deep frozen fruit.....   | 72  |
| Figure 2.7: Manufacture of various tomato products.....  | 73  |
| Figure 2.8: Crude oil chemical refining.....   | 77  |
| Figure 2.9: Short time pasteurised milk process.....   | 80  |
| Figure 2.10: Production of UHT milk .....  | 81  |
| Figure 2.11: Production of sterilised milk .....   | 82  |
| Figure 2.12: Flow sheet of processes for condensed products (e.g. UHT condensed milk) and<br>intermediate products (e.g. milk concentrates)..... | 83  |
| Figure 2.13: Flow sheet of powdered milk production.....   | 84  |
| Figure 2.14: Continuous buttermaking .....   | 85  |
| Figure 2.15: Manufacture of cheese .....   | 86  |
| Figure 2.16: Yoghurt production .....  | 88  |
| Figure 2.17: Summary of the dry pasta production process.....  | 91  |
| Figure 2.18: An example maize starch production process .....  | 93  |
| Figure 2.19: An example wheat starch production process .....  | 94  |
| Figure 2.20: An example potato starch production process.....  | 95  |
| Figure 2.21: Instant coffee manufacturing.....   | 103 |
| Figure 2.22: Citric acid fermentation process.....   | 111 |
| Figure 3.1: Output stream terminology used in the FDM sector .....   | 113 |
| Figure 3.2: Water consumption by the German FDM industries in 1998.....  | 116 |
| Figure 3.3: Consumption and emission levels of the process steps in fish canning.....  | 158 |
| Figure 3.4: Consumption and emission levels of the process steps in filleting and preserving fish .....  | 159 |
| Figure 3.5: Consumption and emission levels of the process steps in crustaceans processing.....  | 160 |
| Figure 3.6: Consumption and emission levels of the process steps in mollusc processing.....  | 161 |
| Figure 3.7: Waste water produced in fruit and vegetable processing .....   | 168 |
| Figure 3.8: Type and amount of wastes produced in fruit and vegetable processing and<br>preservation .....                                       | 170 |
| Figure 3.9: Type and amount of wastes produced in fruit and vegetable juice manufacturing.....   | 171 |
| Figure 3.10: Types and quantities of wastes and by-products generated in vegetable oil processing .....  | 183 |
| Figure 3.11: Water consumption/processed milk ratio as a function of the quantity of processed<br>milk.....                                      | 186 |
| Figure 3.12: Typical losses of milk in the dairy industry .....  | 189 |
| Figure 3.13: Type and amount of wastes produced in milk processing.....  | 191 |
| Figure 3.14: Type and amount of wastes produced in yoghurt processing.....   | 192 |
| Figure 3.15: Type and amount of wastes produced in cheese processing.....  | 192 |
| Figure 3.16: Type and amount of waste water, wastes and by-products from sugar beet processing.....  | 199 |
| Figure 3.17: Input and output figures for large German breweries (capacity over 1 million hl beer)<br>per hl of beer sold .....                  | 202 |
| Figure 3.18: Co-product, by-product and solid waste quantities from a 1 million hl beer/yr brewery .....   | 205 |
| Abbildung 4.1: Einfluss der Anzahl der Schaufelblätter auf die Geräuschübertragungsdistanz.....  | 221 |
| Abbildung 4.2: Minderung der Lärmemissionen an einem Industrieschornstein .....  | 226 |
| Abbildung 4.3: Verringerung des Energieverbrauchs.....   | 229 |
| Abbildung 4.4: Beispiel für eine Methodik zur Abfallvermeidung und -reduzierung.....   | 231 |
| Abbildung 4.5: Beispielarbeitsblatt zur Identifizierung von Einträgen/Austrägen und<br>Umweltproblemen .....                                     | 232 |
| Abbildung 4.6: Übersicht über die Wasserzufuhr und -abgabe einer Beispielanlage.....   | 233 |
| Abbildung 4.7: Ausführliches Prozessfließdiagramm für die Flüssigmilchproduktion.....  | 237 |
| Abbildung 4.8: Abfallreduktion in der Tierfutterherstellung.....   | 248 |
| Abbildung 4.9: Molkerückgewinnung unter Einsatz der Trübungsmessung.....   | 267 |
| Abbildung 4.10: Prozessablaufdiagramm eines CO <sub>2</sub> -Konditionierungssystems in einer großen<br>Brauerei .....                           | 277 |
| Abbildung 4.11: Rückgewinnung von Wärme und Öl: Wärmetauscher in der Abzugshaube einer<br>Frittieranlage .....                                   | 284 |
| Abbildung 4.12: Prinzip der Fallfilmverdampfung.....   | 287 |
| Abbildung 4.13: Milchverdampfung im Fallfilmverfahren .....  | 288 |

|   |     |
|---|-----|
| Abbildung 4.14: Prinzip der MBV .....   | 290 |
| Abbildung 4.15: Flussdiagramm eines vierstufigen MBV-Verdampfersystems.....   | 291 |
| Abbildung 4.16: Vergleich der Betriebskosten für TBV- und MBV-Verdampfer .....  | 292 |
| Abbildung 4.17: Optimierung der Gefriertunnel bei der Produktion von Tiefkühlgemüse.....  | 297 |
| Abbildung 4.18: Vergleich der Energieeffizienz eines konventionellen Gasturbinengenerators und<br>einer KWK-Anlage .....                          | 306 |
| Abbildung 4.19: Flussdiagramm eines KWK-Systems in einer Brauerei .....   | 307 |
| Abbildung 4.20: Binäres-System mit konventioneller Kühlanlage.....  | 318 |
| Abbildung 4.21: Flussdiagramm eines Cleaning-in-place-Systems.....  | 339 |
| Abbildung 4.22: Flussdiagramm für die Auswahl von Geruchsminderungstechniken .....  | 343 |
| Abbildung 4.23: Flussdiagramm zur Auswahl von Geräten und Ausrüstungen zur<br>Geruchsminderung (**siehe Tabelle 4.32) .....                       | 354 |
| Abbildung 4.24: Funktionsprinzip eines Zyklons .....  | 356 |
| Abbildung 4.25: Typischer Aufbau eines elektrostatischen Abscheiders (nur zwei Zonen<br>dargestellt).....   | 361 |
| Abbildung 4.26: Arten und Unterteilung von Filtern .....  | 362 |
| Abbildung 4.27: Röhrenfiltersystem in einer großen Molkerei.....  | 363 |
| Abbildung 4.28: Foto einer industriellen Schlauchfilterkammer .....   | 365 |
| Abbildung 4.29: Plan eines Schütttschichtabsorbers.....   | 369 |
| Abbildung 4.30: Schema eines Prallplattenwäschers .....   | 371 |
| Abbildung 4.31: Schema einer Sprühkammer.....   | 372 |
| Abbildung 4.32: Schema eines Biofilters.....  | 376 |
| Abbildung 4.33: Schema eines Biowäschers.....   | 380 |
| Abbildung 4.34: Schema einer thermischen Nachverbrennungsanlage .....   | 382 |
| Abbildung 4.35: Flussdiagramm zu Ursprung und Prozessmanagement des Rauchgases aus dem<br>Abgasreinigungssystem einer Räucherammer .....          | 385 |
| Abbildung 4.36: Massenbilanz eines Systems zur Behandlung von Abgasen durch thermische<br>Oxidation mit direkter Flamme .....                     | 386 |
| Abbildung 4.37: Schema einer katalytischen Nachverbrennungsanlage.....  | 389 |
| Abbildung 4.38: Industrielle Anlage zur Behandlung mit nicht-thermischem Plasma .....   | 392 |
| Abbildung 4.39: Vereinfachtes Prozessfließbilddiagramm eines Membranbioreaktors.....  | 428 |
| Abbildung 4.40: Das Verfahren der Ammoniakstrippung .....   | 432 |
| Abbildung 4.41: Fließbild der Behandlung von Abwasser aus der Verarbeitung von Fleisch und<br>Geflügel .....                                      | 446 |
| Abbildung 4.42: Fließbild einer im Obst- und Gemüsektor üblichen Abwasserbehandlung .....   | 449 |
| Abbildung 4.43: Kläranlage mit Wiederverwendung des Wassers in einem gemüseverarbeitenden<br>Betrieb.....   | 452 |
| Abbildung 4.44: Wiederverwendung von Wasser in der Konservenindustrie .....   | 453 |
| Abbildung 4.45: Übliche Abwasserbehandlung in Molkereien .....  | 459 |
| Abbildung 4.46: Wasserkreislauf in einer Kartoffelstärkeanlage.....   | 461 |
| Abbildung 4.47: Übliche Möglichkeiten der Behandlung von Zuckerrübenabwasser .....  | 465 |
| Abbildung 4.48: Anaerobe/aerobe Abwasserbehandlung in einer Brennerei.....  | 471 |
| Abbildung 4.49: Anlage für die trockene Eingeweideentfernung .....  | 484 |
| Abbildung 4.50: Dampfschälprozess in einer Beispielanlage in Finnland.....  | 490 |
| Abbildung 4.51: Flussdiagramm der Kartoffel- und Karottenverarbeitung in einer finnischen<br>Anlage.....  | 493 |
| Abbildung 4.52: Installation eines Wasserkühlers in einer Eiswasserrinne .....  | 501 |
| Abbildung 4.53: Installation einer Verdampferplatte unter der Eiswasserrinne.....   | 501 |
| Abbildung 4.54: Zweiphasen- und das Dreiphasen-Olivenölextraktionsverfahren.....  | 505 |
| Abbildung 4.55: Grundfließbild eines Gegenstrom-DT .....  | 508 |
| Abbildung 4.56: Grundfließbild der Brüden-Wärme-Integration im DT .....   | 509 |
| Abbildung 4.57: Mineralölsystem und zugehörige Prozessschritte .....  | 511 |
| Abbildung 4.58: Verfahrensfließbild für die Hexanrückgewinnung aus Prozesswasser bei der<br>Extraktion nicht raffinierter pflanzlicher Öle.....   | 512 |
| Abbildung 4.59: Grundfließbild für die chemische Raffination von pflanzlichen Ölen .....  | 513 |
| Abbildung 4.60: Grundfließbild für die Säureentschleimung von pflanzlichem Öl.....  | 516 |
| Abbildung 4.61: Grundfließbild der Nassstaubemissionsabscheidung durch Zyclone .....  | 519 |
| Abbildung 4.62: Grundfließbild der Doppelwäscheranordnung bei der Desodorierung.....  | 522 |
| Abbildung 4.63: Grundfließbild eines geschlossenen alkalischen Kreislaufs mit Kühlung als Teil<br>eines Vakuumsystems für die Desodorierung ..... | 524 |
| Abbildung 4.64: Grundfließbild eines Dämpfers in Kombination mit einem Wäscher und einem<br>Trockenkondensationssystem .....                      | 525 |
| Abbildung 4.65: Grundfließbild für die Milchherstellung in einer Molkerei ].....  | 529 |

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|  |     |
|--|-----|
| Abbildung 4.66: Zweistufiges Trocknungsverfahren] in einer großen Molkerei.....  | 532 |
| Abbildung 4.67: Aseptische Abfüllung von UHT-Milch ohne Aseptikkammer .....  | 534 |
| Abbildung 4.68: Fließbild einer Membranverarbeitungsanlage .....   | 544 |
| Abbildung 4.69: Schematische Darstellung der Verdampfungstrocknung mit<br>Wirbelschichttrocknern für die Trocknung von Zuckerrübenschnitzeln ..... | 553 |
| Abbildung 4.70: KWK- und Dampfsystem einer zuckerproduzierenden Anlage, in der<br>Zuckerrübenschnitzel mit Dampf getrocknet werden.....            | 554 |
| Abbildung 4.71: Hochtemperaturtrocknung von Zuckerrübenschnitzeln.....   | 555 |
| Abbildung 4.72:Zweistufentrocknung von Zuckerrübenschnitzeln.....  | 556 |
| Abbildung 4.73: Verringerung des Erdanteils in Schweden.....   | 560 |
| Abbildung 4.74: In einem deutschen Kaffeeunternehmen betriebener Chargenröster .....   | 564 |
| Abbildung 4.75: Kontinuierliche Kaffeeröstung in einem deutschen Unternehmen .....   | 565 |
| Abbildung 4.76: Prinzip der Cross-Flow-Filtration im Vergleich zur Dead-End-Filtration.....  | 572 |
| Abbildung 4.77: Fließbild der Herstellung alkoholischer Getränke .....   | 574 |
| Abbildung 4.78: Fließbild der Abfülllinie .....  | 574 |
| Abbildung 4.79: Einzelne Stufen der Flaschenreinigung und -spülung.....  | 578 |
| Abbildung 4.80: Verfahren zur Flaschenreinigung mit Überwachung des pH-Wertes zwecks<br>Reduzierung des Wasserverbrauchs .....                     | 578 |
| Abbildung 4.81: CIP-System für ein Abfüllverfahren in einer Brauerei .....   | 580 |
| Abbildung 4.82: Wärmerückgewinnung aus einem mit Dampf erhitzten Würzekessel zur<br>Erzeugung von Heißwasser .....                                 | 587 |
| Abbildung 4.83: Wärmerückgewinnung aus der Erwärmung der Würze zum Vorheizen der Würze<br>vor dem Kochen .....                                     | 588 |
| Abbildung 5.1: Darstellung der BVT-Schlussfolgerungen für Anlagen der Nahrungsmittelindustrie .....  | 595 |

## List of tables

|   |     |
|---|-----|
| Table 1.1: Structure/production by countries (1998).....  | 1   |
| Table 1.2: Structure/production by sector in EU-15.....   | 1   |
| Table 1.3: EU-15 production in the major sectors (1999).....  | 2   |
| Table 1.4: Top export destinations of EU-15 FDM products in 2001 (EUR million).....   | 3   |
| Table 1.5: Exports from EU-15, by sectors in 2000.....  | 4   |
| Table 1.6: Environmental issues for some FDM sectors.....   | 7   |
| Table 2.1: The processing techniques and unit operations most commonly used in the FDM sector.....                            | 10  |
| Table 2.2: Examples of heat treatment combinations used in the FDM sector.....  | 40  |
| Table 2.3: Typical total solids concentrations for various types of evaporators.....  | 41  |
| Table 2.4: Typical freezing points of various FDM products.....   | 46  |
| Table 2.5: Typical gas mix composition for gas flushing.....  | 51  |
| Table 2.6: Unit operations applied in different sectors.....  | 60  |
| Table 2.7: Summary of the possible processing routes of some fruit and vegetables.....  | 70  |
| Table 2.8: Solvent decaffeination process.....  | 104 |
| Table 2.9: Water decaffeination process.....  | 105 |
| Table 3.1: Quantitative benchmarking parameters applicable in the FDM sector.....   | 114 |
| Table 3.2: Percentage of raw materials which end up in the final product in some processes.....                               | 115 |
| Table 3.3: BOD <sub>5</sub> equivalent of general FDM constituents and some products.....                                     | 117 |
| Table 3.4: Environmental impacts of the FDM unit operations.....  | 122 |
| Table 3.5: Codes used for emissions to air.....   | 123 |
| Table 3.6: Codes used for emissions to water.....   | 123 |
| Table 3.7: Codes used for solid outputs.....  | 123 |
| Table 3.8: Typical energy requirement per tonne of cocoa.....   | 133 |
| Table 3.9: Summary of water consumption and waste water volumes in the FDM sector.....  | 149 |
| Table 3.10: By-products in cutting and deboning meat.....   | 150 |
| Table 3.11: Consumption and emission levels for cooked ham manufacturing in Italy.....  | 151 |
| Table 3.12: Specific consumption of water and energy and emissions of waste water in salami and<br>sausage production.....    | 152 |
| Table 3.13: Consumption and emission levels for preserved meat products manufacturing in Italy.....                           | 153 |
| Table 3.14: Consumption and emission levels for cured ham manufacturing in Italy.....   | 154 |
| Table 3.15: Consumption and emission levels for canned meat in Italy.....   | 155 |
| Table 3.16: Specific water consumption and organic load in Nordic countries.....  | 156 |
| Table 3.17: Waste water from fish filleting.....  | 157 |
| Table 3.18: Typical waste water production rates and characteristics for fish processing in<br>Germany.....                   | 157 |
| Table 3.19: Water consumption levels achieved in fruit and vegetable installations.....                                       | 162 |
| Table 3.20: Water consumption for some processes in the fruit and vegetable sector.....                                       | 162 |
| Table 3.21: Consumption and emission levels for canning tomatoes.....   | 163 |
| Table 3.22: Consumption and emission levels for manufacturing of tomato juice, puree and paste.....                           | 164 |
| Table 3.23: Average waste water and water pollution generated in the US canning industry in 1975.....                         | 164 |
| Table 3.24: BOD and TSS concentrations in waste water from fruit and vegetable processing.....                                | 165 |
| Table 3.25: Waste water characteristics from some fruit and vegetable processing.....   | 165 |
| Table 3.26: Waste water volume and water pollution per unit of product generated in the<br>processing of some vegetables..... | 166 |
| Table 3.27: Waste water volume and water pollution per unit of product generated in the<br>processing of some fruit.....      | 167 |
| Table 3.28: Solid waste produced during fruit and vegetable processing.....   | 169 |
| Table 3.29: Fruit and vegetable wastes in juice manufacturing in Hungary.....   | 171 |
| Table 3.30: Waste water values of brine during the production of Sauerkraut.....  | 175 |
| Table 3.31: Electricity consumption during the sorting of vegetables.....   | 175 |
| Table 3.32: Energy carrier and consumption for the caustic peeling of vegetables.....   | 176 |
| Table 3.33: Energy carrier and consumption for the steam peeling of vegetables.....   | 176 |
| Table 3.34: Electricity consumption for the washing of vegetables.....  | 176 |
| Table 3.35: Electricity consumption of mechanical processing of vegetables before freezing.....                               | 176 |
| Table 3.36: Energy source and consumption for drum blanching in the deep freezing of vegetables.....                          | 177 |
| Table 3.37: Energy source and consumption for countercurrent water cooling of vegetables<br>processing.....                   | 177 |
| Table 3.38: Energy carrier and consumption for a belt blancher with water cooling in vegetable<br>processing.....             | 177 |

|   |     |
|---|-----|
| Table 3.39: Energy carrier and order of magnitude indicators of a belt blancher with air cooling in vegetable processing.....             | 177 |
| Table 3.40: Waste water production in vegetable oil manufacturing steps.....  | 179 |
| Table 3.41: Waste water characteristics in vegetable oil processing.....  | 179 |
| Table 3.42: Reported untreated waste water characteristics in vegetable oil refining (cornflower, cottonseed and sunflower).....          | 180 |
| Table 3.43: Characteristics of olive oil mill waste water.....  | 180 |
| Table 3.44: Hexane emission to air.....   | 180 |
| Table 3.45: Summary of air emissions in the manufacturing of crude vegetable oils.....  | 181 |
| Table 3.46: Summary of key solid/liquid emissions and by-products in the manufacturing of crude vegetable oils.....                       | 182 |
| Table 3.47: Summary of solid output from manufacturing crude vegetable oils.....  | 182 |
| Table 3.48: Energy consumption in crude vegetable oil refining.....   | 184 |
| Table 3.49: Water consumption in European dairies.....  | 186 |
| Table 3.50: Water consumption for some Nordic dairies.....  | 186 |
| Table 3.51: Approximate volumes of waste water in dairy activities.....   | 187 |
| Table 3.52: Reported untreated dairy waste water contamination levels.....  | 188 |
| Table 3.53: Volume and pollution levels of dairy waste water in Europe.....   | 188 |
| Table 3.54: Typical BOD levels of various milk products.....  | 188 |
| Table 3.55: Composition of cheese manufacturing waste water.....  | 190 |
| Table 3.56: Product losses in some processes in the dairy industry.....   | 191 |
| Table 3.57: Solid output per tonne of processed milk.....   | 191 |
| Table 3.58: Production and disposal of solid wastes from some Nordic dairies.....   | 193 |
| Table 3.59: Energy consumption in European dairies.....   | 193 |
| Table 3.60: Total energy consumption for some Nordic dairies.....   | 194 |
| Table 3.61: Consumption of cleaning agents used in European dairies.....  | 194 |
| Table 3.62: Consumption of cleaning chemicals used in some Nordic dairies.....  | 194 |
| Table 3.63: Air emissions from pasta manufacturing.....   | 195 |
| Table 3.64: Energy consumption in the Italian pasta industry.....   | 196 |
| Table 3.65: Water consumption in the starch industry.....   | 196 |
| Table 3.66: Solid outputs from the starch industry.....   | 197 |
| Table 3.67: Energy consumption in the starch industry.....  | 197 |
| Table 3.68: Water consumption in Danish sugar factories.....  | 198 |
| Table 3.69: Energy consumption in Danish sugar factories.....   | 200 |
| Table 3.70: Average specific waste water discharges.....  | 200 |
| Table 3.71: Waste water characteristics in processes of a red winery.....   | 201 |
| Table 3.72: Water consumption for different brewery processes.....  | 203 |
| Table 3.73: Waste water production in different brewery processes.....  | 203 |
| Table 3.74: Untreated waste water characteristics for breweries.....  | 204 |
| Table 3.75: Waste water and pollution generated in breweries.....   | 204 |
| Table 3.76: Energy consumption of German breweries with more than 20 employees.....   | 206 |
| Table 3.77: Heat consumption for different brewery processes.....   | 206 |
| Table 3.78: Solid wastes and by-products in the citric acid fermentation process.....   | 207 |
| Tabelle 4.1: Gliederung der Angaben zu den Techniken, die bei der Festlegung der BVT berücksichtigt werden.....                           | 209 |
| Tabelle 4.2: Leitwerte zur Lärminderung durch Verringerung der Umdrehungszahl von Ventilatoren.....                                       | 220 |
| Tabelle 4.3: Beispielarbeitsblatt für die Aufschlüsselung des Energieverbrauchs.....  | 235 |
| Tabelle 4.4: Beispiele für Ursachen von Materialverlusten und Methoden zur Pflege eines genauen Bestandsverzeichnisses.....               | 236 |
| Tabelle 4.5: Hauptbereiche der Entstehung von Abfallmilch.....  | 237 |
| Tabelle 4.6: Normalerweise erzielbare Reduzierung des Wasserverbrauchs.....   | 238 |
| Tabelle 4.7: Für eine als Beispiel genannte Speiseölraffinerie angegebene Kosten und Einsparungen beim Einsatz der Pinch-Technologie..... | 240 |
| Tabelle 4.8: Beispiele für Quellen von Tierfutter aus der Produktion von Nahrungsmitteln für den menschlichen Verzehr.....                | 252 |
| Tabelle 4.9: Lärmmessungen (Mittelwerte dreier unabhängiger Messungen) aus einer deutschen Brauerei.....                                  | 256 |
| Tabelle 4.10: Berechnete Teilbeurteilungspegel für Materialtransport- und Umschlagsprozesse.....  | 257 |
| Tabelle 4.11: Beispiele für die Verwendung von Füllstandssensoren in der Nahrungsmittelverarbeitung.....                                  | 260 |
| Tabelle 4.12: Beispiele für den Einsatz von Durchflussregulierung in der Nahrungsmittelproduktion.....                                    | 262 |

|   |     |
|---|-----|
| Tabelle 4.13: Typische Anwendungen der Durchflussmessung im Nahrungsmittelsektor .....  | 262 |
| Tabelle 4.14: Beispiele für den Einsatz von pH-Messungen in der Nahrungsmittelproduktion .....  | 263 |
| Tabelle 4.15: Typische Anwendungen der pH-Messung in der Nahrungsmittelproduktion .....   | 263 |
| Tabelle 4.16: Beispiele für den Einsatz von Leitfähigkeitsmessungen in der<br>Nahrungsmittelproduktion .....  | 265 |
| Tabelle 4.17: Typische Anwendungen der Leitfähigkeitsmessung in der Nahrungsmittelproduktion.....   | 265 |
| Tabelle 4.18: Beispiele für den Einsatz von Trübungsmessungen in der Nahrungsmittelproduktion.....  | 267 |
| Tabelle 4.19: Umweltauswirkungen der verschiedenen Methoden zur Raucherzeugung.....   | 278 |
| Tabelle 4.20: Vergleich der Effizienz bei Mehrfacheffektverdampfern in der Milchwirtschaft .....  | 289 |
| Tabelle 4.21: Optimalwerte der Rauchanalyse in einer Anlage zur Herstellung von Teigwaren.....  | 309 |
| Tabelle 4.22: Vergleich der Volumina von Binäreis und Sole, die zur Erzielung einer<br>Temperaturabsenkung um 3 °C erforderlich sind .....                          | 319 |
| Tabelle 4.23: Erforderliche Kühlleistung einer Binäreis-Anlage .....  | 319 |
| Tabelle 4.24: Potenzielle Einsparungen durch die Reduzierung des Kesselabblasens beim<br>Tiefkühlen von Gemüse .....  | 323 |
| Tabelle 4.25: Umweltnutzen und Kostenminderung durch den Einsatz von Molchsystemen .....  | 328 |
| Tabelle 4.26: Datenblatt für die Erhebung von Angaben zu übelriechenden Emissionen .....  | 345 |
| Tabelle 4.27: Checkliste für außergewöhnlichen Betrieb .....  | 345 |
| Tabelle 4.28: Typisches Geruchsmessungsprogramm mit vereinfachten Messungen eines nicht<br>näher genannten Betriebs, in dem Nahrungsmittel hergestellt werden ..... | 346 |
| Tabelle 4.29: Nachsorgende Techniken zur Verminderung von Luftverschmutzungen .....   | 347 |
| Tabelle 4.30: Schlüsselparameter für die Auswahl der nachsorgenden Technik .....  | 348 |
| Tabelle 4.31: Abscheidungstechniken im Vergleich.....   | 349 |
| Tabelle 4.32: Zusammenfassung allgemeiner Kriterien für die Auswahl von Geruchs-/VOC-<br>Minderungstechniken.....   | 353 |
| Tabelle 4.33: Luftentstaubung – Übersicht über Nassabscheider .....   | 359 |
| Tabelle 4.34: Vergleich verschiedener Schlauchfiltersysteme .....   | 364 |
| Tabelle 4.35: Typische Richtwerte für die Absorberplanung.....  | 368 |
| Tabelle 4.36: Eigenschaften von Aktivkohle .....  | 373 |
| Tabelle 4.37: Funktionsprinzipien der wichtigsten Adsorbenttypen.....   | 374 |
| Tabelle 4.38: Vor- und Nachteile der biologischen Behandlung .....  | 376 |
| Tabelle 4.39: Betriebsbedingungen bei verschiedenen Stufen der thermischen Oxidation.....   | 382 |
| Tabelle 4.40: Technische Daten einer thermischen Nachverbrennungsanlage mit direkter Flamme<br>in einer Räucherammer .....  | 384 |
| Tabelle 4.41: Technische Daten einer thermischen Nachverbrennungsanlage mit direkter Flamme<br>in einer Räucherammer .....  | 386 |
| Tabelle 4.42: Geruchsreduktion durch Behandlung mit nicht-thermischem Plasma .....  | 393 |
| Tabelle 4.43: Abgasvolumen in Anlagen zur Reduktion von Geruchsemissionen mit Hilfe von<br>nicht-thermischem Plasma .....   | 393 |
| Tabelle 4.44: Beispiele für Abwasserbehandlungstechniken .....  | 400 |
| Tabelle 4.45: Beispiele üblicher Anwendungen von Abwasserbehandlungstechniken in der<br>Nahrungsmittelproduktion .....  | 401 |
| Tabelle 4.46: Übliche Qualität von Abwasser aus der Nahrungsmittelproduktion nach Behandlung.....   | 401 |
| Tabelle 4.47: Zusammenfassung von Abwasserbehandlungsverfahren in verschiedenen Branchen .....  | 402 |
| Tabelle 4.48: Geschätzte Verringerung der Verschmutzung im Fischsektor durch<br>Trommeldrahtsiebe .....   | 404 |
| Tabelle 4.49: Übliche Leistungsdaten im Brauereisektor nach der Sedimentation .....   | 407 |
| Tabelle 4.50: Vor- und Nachteile der Sedimentation .....  | 408 |
| Tabelle 4.51: Abscheideeffizienz der Entspannungsflotation in einer Heringsfiletieranlage.....  | 409 |
| Tabelle 4.52: Abscheideeffizienz der Zentrifugation in der Heringsindustrie .....   | 410 |
| Tabelle 4.53: Phosphoreliminierungsleistung einer gleichzeitigen Belebtschlammbehandlung und<br>Fällung in Kläranlagen im Kartoffelstärkektor .....                 | 411 |
| Tabelle 4.54: Vor- und Nachteile anaerober Abwasserbehandlungen im Vergleich zu aeroben<br>Verfahren .....  | 413 |
| Tabelle 4.55: Vor- und Nachteile aerober Behandlungsverfahren .....   | 414 |
| Tabelle 4.56: Leistungsdaten einer Belebtschlammkläranlage im Brauereisektor .....  | 414 |
| Tabelle 4.57: Betrieb einer normalen SBR-Anlage.....  | 417 |
| Tabelle 4.58: Übliche Verfahrens- und Leistungswerte anaerober Abwasserbehandlungsverfahren] .....  | 423 |
| Tabelle 4.59: Übliche Probleme, die bei biologischen Behandlungsverfahren auftreten können .....  | 423 |
| Tabelle 4.60: Angegebene Leistungsfähigkeit eines UASB-Reaktors in einer Brauerei .....   | 425 |
| Tabelle 4.61: Angegebene Leistungsfähigkeit eines EGSB-Reaktors in einer Brauerei.....  | 427 |
| Tabelle 4.62: Parameter für die Ammoniakstrippung von Abwasser aus der Zuckerindustrie<br>(Kondensat).....  | 432 |

|  |     |
|--|-----|
| Tabelle 4.63: Wirksamkeit verschiedener Abwasserbehandlungsverfahren zur Entfernung von Phosphor.....  | 433 |
| Tabelle 4.64: Gemeldete Leistungsdaten eines ICW.....  | 440 |
| Tabelle 4.65: Eigenschaften von unbehandeltem Abwasser aus der fischverarbeitenden Industrie und Effizienz von Vorbehandlungen.....  | 447 |
| Tabelle 4.66: Kombinierte Abwasserbehandlungsverfahren, die aus dem Obst- und Gemüsesektor gemeldet werden.....  | 450 |
| Tabelle 4.67: Qualitätsparameter für behandeltes Abwasser, Rohwasser und Prozesswasser.....  | 451 |
| Tabelle 4.68: Qualität des Grundwassers für einen gemüseverarbeitenden Betrieb im Vergleich zu den WHO-Richtwerten.....  | 451 |
| Tabelle 4.69: Vergleich alternativer Behandlungsverfahren für Abwasser aus der Olivenölherstellung.....  | 455 |
| Tabelle 4.70: Eigenschaften des Abwassers vor und nach der Behandlung.....   | 456 |
| Tabelle 4.71: Energieverbrauchswerte.....  | 456 |
| Tabelle 4.72: Beschreibung eines Systems zur Abwasserbehandlung in einer Anlage der Öl- und Fettverarbeitung.....  | 457 |
| Tabelle 4.73: Zusammenfassung der Anwendungsparameter.....   | 457 |
| Tabelle 4.74: Eigenschaften von Abwasser aus dem Stärkesektor nach der Behandlung.....   | 460 |
| Tabelle 4.75: Aufkonzentrierung von Kartoffelstärke-Prozesswasser durch Verdampfung – Planungsdaten.....   | 462 |
| Tabelle 4.76: Merkmale der biologischen Abwasserbehandlung in einer Kartoffelstärkeanlage.....   | 462 |
| Tabelle 4.77: Leistung der Abwasserbehandlung in einer Anlage der Zuckerindustrie in Nordeuropa.....   | 465 |
| Tabelle 4.78: Abwassermengen und deren -eigenschaften in Anlagen der dänischen Zuckerindustrie.....  | 466 |
| Tabelle 4.79: Abwasserfrachten nach der biologischen Behandlung während einer Zuckerrübensaison.....   | 466 |
| Tabelle 4.80: Eigenschaften des Abwassers einer Brauerei.....  | 469 |
| Tabelle 4.81: Zusammenfassung der Frachtreduktion bei der Behandlung von Läuterbottichabwasser.....  | 470 |
| Tabelle 4.82: Konzentrationen im Abwasser aus der Zitronensäurefermentation nach der Behandlung pro Tonne der installierten Produktionskapazität.....  | 472 |
| Tabelle 4.83: Abwasserbelastung vor und nach der Einführung der trockenen Eingeweidebeseitigung.....   | 484 |
| Tabelle 4.84: Techniken, die in Heringsindustrie eingesetzt werden, um Wasserverbrauch und Abwasserverschmutzung zu senken.....  | 486 |
| Tabelle 4.85: Energieträger und Verbrauch bei der Dampfschälung vor dem Einfrieren von Gemüsen.....  | 489 |
| Tabelle 4.86: Auswirkung einer Kombination aus Vorschälern mit Karborundum und anschließender Messerschälung auf die Wasserverschmutzung bei der Herstellung von halben Birnen in Sirup..... | 492 |
| Tabelle 4.87: Auswirkung der Laugenschälung auf die Wasserverschmutzung bei der Herstellung von halben Birnen in Sirup.....  | 494 |
| Tabelle 4.88: Energieträger und Verbrauch bei der Laugenschälung vor dem Einfrieren von Gemüse.....  | 494 |
| Tabelle 4.89: Vergleich des Energie- und Wasserverbrauchs bei den verschiedenen Blanchiertechniken.....  | 496 |
| Tabelle 4.90: Energieträger und Verbrauch beim Förderbandblanchieren mit Wasserkühlung.....  | 498 |
| Tabelle 4.91: Energieträger und Verbrauch beim Förderbandblanchieren mit Luftkühlung.....  | 499 |
| Tabelle 4.92: Energieträger und Größenangaben beim Trommelblanchieren.....   | 500 |
| Tabelle 4.93: Energieträger und Verbrauch bei der Gegenstrom-Wasserkühlung.....  | 500 |
| Tabelle 4.94: Beispiele für die Wiederverwendung von Wasser im Obst- und Gemüsesektor.....   | 503 |
| Tabelle 4.95: Vergleich der Durchsätze beim Dreiphasen- und Zweiphasen-Olivenölverfahren.....  | 506 |
| Tabelle 4.96: Vor- und Nachteile des Zweiphasensystems im Vergleich zu den Dreiphasensystemen bei der Olivenölproduktion.....  | 507 |
| Tabelle 4.97: Energieverbrauch des DT und der nachgeschalteten Trocknung bei der Extraktion von Ölsaaten.....  | 508 |
| Tabelle 4.98: Verbrauchs- und Emissionswerte für die chemische Raffination von pflanzlichen Ölen.....  | 514 |
| Tabelle 4.99: Verbrauchszahlen für die konventionelle und die enzymatische Entschleimung von pflanzlichem Öl.....  | 518 |
| Tabelle 4.100: Kosten für die konventionelle und die enzymatische Entschleimung von pflanzlichem Öl.....   | 518 |

|  |     |
|--|-----|
| Tabelle 4.101: Vergleich der Kühlsysteme, die zur Vakuumzeugung bei der Desodorierung von pflanzlichen Ölen benutzt werden.....  | 521 |
| Tabelle 4.102: Energiedaten eines Doppelwäschers, der mit einem Durchlaufkühlsystem kombiniert ist.....  | 523 |
| Tabelle 4.103: Energiedaten für einen geschlossenen alkalischen Kreislauf im Vakuumsystem der Desodorierung/Dämpfung.....  | 524 |
| Tabelle 4.104: Leistungsdaten eines Beispiel-Trockenkondensationssystems.....  | 526 |
| Tabelle 4.105: Einsparungen beim Wasser- und Energieverbrauch in einer Molkerei, die den Proteingehalt durch Ultrafiltration standardisiert.....                       | 538 |
| Tabelle 4.106: Zusammensetzung des Abwassers aus der Käseherstellung.....  | 539 |
| Tabelle 4.107: Möglichkeiten der Wiederverwendung von Wasser in Molkereien.....  | 543 |
| Tabelle 4.108: Charakteristische Nieder-/Hochtemperaturtrocknung von Zuckerrübenschnitzeln.....  | 548 |
| Tabelle 4.109: Standardisierte Rahmenbedingungen der drei Beispielanlagen in Deutschland.....  | 556 |
| Tabelle 4.110: Vergleich der Energiebilanzen von drei verschiedenen Verfahren zur Trocknung von Rübenschnitzeln und für eine Anlage ohne Trocknung in Deutschland..... | 557 |
| Tabelle 4.111: Vergleich der Energiekosten für verschiedene Methoden der Trocknung von Rübenschnitzeln.....  | 558 |
| Tabelle 4.112: Vergleich der Aufwendungen, ausgedrückt als NPV.....  | 559 |
| Tabelle 4.113: Staubgehalt hinter dem Zyklon.....  | 565 |
| Tabelle 4.114: Zusammensetzung des Abgases aus der Luftkühlung vor Behandlung.....   | 566 |
| Tabelle 4.115: Vergleich der Verbrauchs- und Emissionswerte der verschiedenen Kaffeeröstverfahren.....   | 568 |
| Tabelle 4.116: Verbrauchs- und Emissionswerte der Abfülllinie (2000).....  | 576 |
| Tabelle 4.117: Werte für Produktion, Energieverbrauch und Abwassermenge einer Anlage zur Produktion alkoholischer Getränke von 1999 bis 2001.....                      | 576 |
| Tabelle 4.118: Vergleich alter und neuer Technik in Bezug auf den durchschnittlichen Energieverbrauch.....   | 577 |
| Tabelle 4.119: Einsparmöglichkeiten bei Wasser und Abwasser in einer Brauerei.....   | 584 |
| Tabelle 4.120: Normalerweise erzielbare Einsparungen beim Wasserverbrauch in Brauereien.....   | 585 |
| Tabelle 4.121: Energieverbrauch im Sudhaus einer großen Brauerei, in der beim Maischen das Infusionsverfahren angewandt wird.....                                      | 585 |
| Tabelle 4.122: Verbrauchswerte für die Trocknung von DDGS.....   | 589 |
| Tabelle 4.123: Verbrauchs- und Emissionswerte der Verdampfungseinrichtung für Melasseschlempe in einer deutschen Melassedestillerie.....                               | 591 |
| Tabelle 5.1: Typische Qualität von Abwasser aus der Nahrungsmittelproduktion nach Behandlung.....  | 604 |
| Tabelle 5.2: Verbrauchs- und Emissionswerte bei der Herstellung von Marktmilch pro Liter angelieferter Milch.....  | 608 |
| Tabelle 5.3: Verbrauchs- und Emissionswerte bei der Produktion von Milchpulver pro Liter angelieferter Milch.....  | 609 |
| Tabelle 5.4: Verbrauchs- und Emissionswerte bei der Produktion von 1 kg Speiseeis.....   | 609 |



## GELTUNGSBEREICH

Dieses Dokument spiegelt einen Informationsaustausch zu den in Anhang 1, Teil 6.4 (b) und (c) der Richtlinie des Rates 96/61/EG vom 24. September 1996 über die integrierte Vermeidung und Verminderung der Umweltverschmutzung (IVU-Richtlinie), aufgeführten Aktivitäten wider, also

6.4. (b) *Behandlung und Verarbeitung zum Zweck der Erzeugung von Nahrungsmittelprodukten aus:*

- *tierischen Rohstoffen (außer Milch) mit einer Produktionskapazität von Fertigerzeugnissen von mehr als 75 Tonnen täglich*
  - *pflanzlichen Rohstoffen mit einer Produktionskapazität von mehr als 300 t Fertigerzeugnissen pro Tag (Vierteljahresdurchschnittswert)*
- c) *Anlagen zur Behandlung und Verarbeitung von Milch, wenn die eingehende Milchmenge 200 t pro Tag übersteigt (Jahresdurchschnittswert).*

Der Geltungsbereich umfasst die gesamte Bandbreite von Aktivitäten, die in europäischen Anlagen anzutreffen sind, deren Kapazität die oben genannten Schwellenwerte übersteigt.

Das Dokument befasst sich nicht mit Aktivitäten in kleinerem Maßstab, wie Catering oder Aktivitäten in Restaurants. Ebenfalls nicht behandelt werden Aktivitäten der Nahrungsmittelindustrie, bei denen keine tierischen oder pflanzlichen Rohstoffe verwendet werden, außer als zugehörige Aktivitäten wie die Verarbeitung von Mineralwasser und die Salzproduktion.

Landwirtschaft, Jagd und Tierschlachtung sind ausgenommen. Die Herstellung von Produkten, die keine Nahrungsmittel sind, z. B. Seifen, Kerzen, Kosmetik, pharmazeutische Stoffe sowie die Herstellung von Gelatine und Leim aus Häuten, Fellen und Knochen sind ebenfalls ausgenommen.

Ein anderes BVT-Merkblatt der Reihe, nämlich das Merkblatt zu „BVT in Tierschlacht- und Tierkörperverwertungsanlagen“ [181, EC, 2003] befasst sich mit der Tierschlachtung. Bei großen Tieren gilt der Schlachtprozess mit der Anfertigung von Standardzerlegungen als beendet, bei Geflügel mit der Erzeugung sauberer, ganzer, verkaufsfertiger Schlachtkörper. Der Geltungsbereich jenes BVT-Merkblatts umfasst auch einige Prozesse zu tierischen Nebenprodukten, in denen unter Umständen Nahrungsmittel hergestellt werden, nämlich das Ausschmelzen von Fett, die Fischmehl- und Fischölproduktion, die Blutverarbeitung und die Gelatineherstellung.

Verpackungen sind allgemein nicht einbezogen, die Verpackung von Nahrungsmittelprodukten in der jeweiligen Anlage jedoch ist abgedeckt.

Auch Tierfutter tierischer und pflanzlicher Herkunft befindet sich im Geltungsbereich dieses Dokuments.

Angaben zu nationalen gesetzlichen Vorgaben und Normen sind nicht in diesem Dokument enthalten. Diese finden sich in einem gesonderten Dokument, das von der Seite „Activities“ der EIPPCB-Internetpräsenz unter der Überschrift „Additional Information“ abgerufen werden kann (siehe <http://eippcb.jrc.es>).



## 1 GENERAL INFORMATION

### 1.1 Description, turnover, growth, employment

The FDM sector produces both finished products destined for consumption and intermediate products destined for further processing. A sectoral breakdown in EU-15 shows that for most FDM product categories production exceeds consumption. The FDM sector in EU-15 had a reported total production value amounting to EUR 593000 million in 2000.

Average real annual growth rates of consumption and production are slow, which is a typical trend for mature markets. For example, growth during 1997 was less than 2 %. In employment terms, the EU-15 FDM sector employs a workforce of 2.7 million. This represents 11 % of the industrial workforce.

Data from some European countries are presented in Table 1.1 and in Table 1.2.

| 1998            | Turnover<br>(EUR million) | Number of<br>employees | Number of<br>companies | Exports<br>(EUR<br>million) | Imports<br>(EUR<br>million) |
|-----------------|---------------------------|------------------------|------------------------|-----------------------------|-----------------------------|
| Austria         | 8000                      | 60579                  | 1386                   | –                           | –                           |
| Belgium         | 22700                     | 86797                  | 6776                   | 10700                       | 9420                        |
| United Kingdom  | 100500                    | 490000                 | 2412                   | 14000                       | 26100                       |
| Czech Republic  | –                         | 142000                 | 947                    | 1000                        | 1520                        |
| Denmark         | 14000                     | 81115                  | 312                    | –                           | –                           |
| The Netherlands | 34000                     | 108000                 | 887                    | –                           | –                           |
| Estonia         | 610                       | 21125                  | 138                    | 228                         | 400                         |
| Finland         | 8160                      | 49000                  | 713                    | 840                         | 1240                        |
| France          | 122400                    | 403000                 | 4250                   | 18000                       | 8300                        |
| Germany         | 116600                    | 545000                 | 6134                   | 19070                       | 23060                       |
| Greece          | 5000                      | 49000                  | 524                    | –                           | –                           |
| Hungary         | 8240                      | 131000                 | 4215                   | 1846                        | 774                         |
| Ireland         | 14000                     | 47000                  | 694                    | –                           | –                           |
| Italy           | –                         | 350000                 | 30000                  | 10300                       | 7200                        |
| Poland          | 19650                     | –                      | –                      | 1180                        | 1270                        |
| Portugal        | 10000                     | 107000                 | 2098                   | –                           | –                           |
| Spain           | 52590                     | 398000                 | 3200                   | 4530                        | 4700                        |
| Sweden          | 13510                     | 60841                  | 830                    | 2110                        | 4500                        |
| <b>Total</b>    | <b>549960</b>             | <b>3129457</b>         | <b>65516</b>           | <b>83804</b>                | <b>88484</b>                |

**Table 1.1: Structure/production by countries (1998)**  
[1, CIAA, 2002]

| 2000                           | Production     |            | Added value    |            | Employees        |            |
|--------------------------------|----------------|------------|----------------|------------|------------------|------------|
|                                | EUR<br>million | %          | EUR<br>million | %          | x10 <sup>3</sup> | %          |
| Processed meat                 | 113000         | 19.1       | 21000          | 15.8       | 588              | 22.1       |
| Fish products                  | 14000          | 2.4        | 3000           | 2.3        | 91               | 3.4        |
| Processed fruit and vegetables | 36000          | 6.1        | 8000           | 6.0        | 174              | 6.5        |
| Vegetable oils and fats        | 23000          | 3.9        | 2000           | 1.5        | 38               | 1.4        |
| Dairy products                 | 95000          | 16.0       | 14000          | 10.5       | 271              | 10.2       |
| Flour and starch products      | 21000          | 3.5        | 4000           | 3.0        | 61               | 2.3        |
| Animal feed                    | 37000          | 6.2        | 6000           | 4.5        | 90               | 3.4        |
| Drinks                         | 98000          | 16.5       | 28000          | 21.1       | 316              | 11.9       |
| Other FDM products             | 156000         | 26.3       | 47000          | 35.3       | 1037             | 38.8       |
| <b>Total</b>                   | <b>593000</b>  | <b>100</b> | <b>133000</b>  | <b>100</b> | <b>2666</b>      | <b>100</b> |

**Table 1.2: Structure/production by sector in EU-15**  
[1, CIAA, 2002]

More detailed figures for the total quantities and values of production in the major sectors of the EU-15 FDM sector, according to Eurostat (1999), are summarised in Table 1.3.

| NACE Code <sup>1</sup> | Code description  | All countries in 1999        |                           |
|------------------------|---|------------------------------|---------------------------|
|                        |   | Total quantity ('000 tonnes) | Total value (EUR million) |
| 15.11                  | Fresh and preserved meat, except poultry  | 26026                        | 40653                     |
| 15.12                  | Fresh and preserved poultry meat  | 6759                         | 11690                     |
| 15.13                  | Meat and poultry meat products  | 11445                        | 34236                     |
| 15.20                  | Processed and preserved fish and fish products  | 4908                         | 12494                     |
| 15.31                  | Potatoes, processed and preserved   | 4054                         | 4246                      |
| 15.32                  | Fruit and vegetable juices  | 7644                         | 5445                      |
| 15.33                  | Processed and preserved fruit and vegetables n.e.c.                                     | 15485                        | 16151                     |
| 15.40                  | Animal and vegetable oils and fats  | 14922                        | 4362                      |
| 15.42                  | Refined oils and fats   | 7466                         | 5445                      |
| 15.43                  | Margarine and similar edible fats   | 2041                         | 3524                      |
| 15.51                  | Dairy products  | 74477                        | 65267                     |
| 15.52                  | Ice-cream and other edible ice  | 1928                         | 3956                      |
| 15.61                  | Grain mill products   | 42587                        | 15431                     |
| 15.62                  | Starches and starch products  | 11058                        | 3764                      |
| 15.71                  | Prepared animal feeds for farm animals <sup>2</sup>                                     | 215045                       | 50091                     |
| 15.72                  | Prepared petfood  | 5115                         | 4505                      |
| 15.81                  | Bread, fresh pastry goods and cakes   | 10620                        | 21360                     |
| 15.82                  | Rusks and biscuits; preserved pastry goods and cakes                                    | 3466                         | 12377                     |
| 15.83                  | Sugar   | 16700                        | 8924                      |
| 15.84                  | Cocoa, chocolate and sugar confectionery  | 5857                         | 22105                     |
| 15.85                  | Pasta, e.g. macaroni, noodles, couscous and similar farinaceous products                | 4930                         | 4934                      |
| 15.86                  | Coffee and tea  | 2102                         | 9747                      |
| 15.87                  | Condiments and seasonings   | 2917                         | 5024                      |
| 15.88                  | Homogenised food preparations and dietetic food   | 624                          | 2616                      |
| 15.89                  | Other food products n.e.c.  | 3784                         | 8416                      |
| 15.91                  | Distilled potable alcoholic drinks  | 1087                         | 5831                      |
| 15.92                  | Ethyl alcohol from fermented materials  | 1367                         | 773                       |
| 15.93                  | Wines   | 13184                        | 20169                     |
| 15.94                  | Other fermented drinks, e.g. cider, perry and mead, and mixed drinks containing alcohol | 379                          | 408                       |
| 15.95                  | Vermouth and other flavoured wine of fresh grapes                                       | 330                          | 449                       |
| 15.96                  | Beer made from malt   | 28030                        | 17256                     |
| 15.97                  | Malt  | 4516                         | 1154                      |
| 15.98                  | Mineral waters and soft drinks  | 64407                        | 26661                     |
|                        | <b>Total value</b>  | <b>615260</b>                | <b>449464</b>             |

<sup>1</sup>The NACE code is a classification of economic activities in the European Union based on an interpretation of the International Standard Industrial Classification (ISIC) [229, EC, 1990].

<sup>2</sup>These figures include both the production by the feed industry (125 million tonnes) and the production by home-mixers. This explains why the turnover mentioned for the feed industry in Table 1.2 is EUR 37000 million and not EUR 50000 million.

**Table 1.3: EU-15 production in the major sectors (1999)**  
[1, CIAA, 2002]

## 1.2 Sector structure

Available statistics show that the EU-15 FDM sector comprises close to 26000 companies, most of which have over 20 employees.

The EU-15 FDM sector is exceptionally diverse compared to many other industrial sectors. This diversity can be seen in terms of the size and nature of companies; the wide range of raw materials, products and processes and the numerous combinations of each, and the production of homogenised global products as well as numerous specialist or traditional products on national and even regional scales. The sector is also subject to very diverse local economic, social and environmental conditions, and varying national legislation.

The EU-15 FDM industry is quite fragmented. Approximately 92 % of the sector is made up of SMEs, although there are some sectors, such as sugar manufacturing, which have very large installations. This fragmentation and diversity, as well as divergent data collection systems in individual MSs, makes it difficult to ascertain exact figures for the sector as a whole.

The sector is spread all over Europe, in very industrialised regions as well as in rural areas. Traditionally, industrial production has been closely related to primary production, climate, and natural resources, e.g. land and water, along with the actual requirements of the particular production technique. These heavily influence the structure and geographical location of specific industrial production. Although this kind of dependence is being reduced, it still holds true in many sectors. For example, some sectors are still concentrated in special regions, e.g. fish processing is usually found in countries, or regions which have direct access to the sea and traditions of fishing, and olive oil is mainly manufactured in Mediterranean countries, especially in Andalusia in Spain. Other activities such as sugar production/refining, grain milling and dairy industries are found in all countries. Some FDM production activities have special requirements of the natural resources, such as the need for receiving waters for the discharge of large volumes of treated waste water. Sugar installations, refineries and fruit and vegetable preservation installations are normally situated near to water, for this reason.

## 1.3 Trade

For many companies, exporting their product out of Europe is an important part of their business. In 2001, the EU-15 FDM sector exports amounted to EUR 45000 million, which represented 79 % of European global exports of agricultural and FDM products. This is a slight decrease over 1998 figures.

The main export market for European FDM products is the US. The Japanese, Swiss and Russian markets are also significant. The top export destinations of EU-15 FDM products in 2001, in financial terms, are shown in Table 1.4.

| Export destination | EUR million  |
|--------------------|--------------|
| United States      | 9085         |
| Japan              | 3716         |
| Switzerland        | 2617         |
| Russia             | 2569         |
| Canada             | 1361         |
| Poland             | 1157         |
| Norway             | 1030         |
| Australia          | 776          |
| Czech Republic     | 767          |
| South Korea        | 741          |
| Algeria            | 721          |
| Israel             | 528          |
| Turkey             | 425          |
| <b>Total</b>       | <b>25493</b> |

**Table 1.4: Top export destinations of EU-15 FDM products in 2001 (EUR million)**  
[3, CIAA, 2001]

The top individual export sectors in the FDM sector in 2000, are shown in Table 1.5.

| <b>Sector</b>             | <b>%</b>    |
|---------------------------|-------------|
| Processed meat            | 11.5        |
| Fish products             | 2.2         |
| Fruit and vegetables      | 6.1         |
| Vegetable oils and fats   | 6.0         |
| Dairy products            | 12.3        |
| Flour and starch products | 4.9         |
| Animal feed               | 4.8         |
| Confectionery             | 9.1         |
| Sugars                    | 3.9         |
| Drinks                    | 30.3        |
| <b>Total</b>              | <b>91.1</b> |

**Table 1.5: Exports from EU-15, by sectors in 2000**  
[1, CIAA, 2002]

## **1.4 Market forces: demand, distribution and competition**

### **1.4.1 Demand**

An ever increasing number of social and economic factors affect FDM consumption patterns throughout the EU-15. These have led to some diversification from traditional consumption and purchasing models. In recent years, European consumers have developed greater homogeneity in lifestyles and this is reflected in the consumption and purchasing patterns for a growing variety of goods. Nevertheless, FDM products still retain elements of cultural specificity linked to national or regional traditions. So although consumers want to be able to purchase the same items and quality of products throughout the whole of the EU-15, they also demand the option/choice of different products linked to their own tradition or culture. This can be reflected at a national, regional or even more local level and can also vary throughout the year.

### **1.4.2 Distribution**

Cost control activities, e.g. labour saving technologies, improvements in logistics and distribution channels and resource saving practices, have been introduced. In general, most FDM products tend to be distributed to the major retail chains, although substantial differences persist between countries.

### **1.4.3 Competition**

As is the case with most mature markets, the FDM sector is facing sharp competitive pressure and progressive market concentration. In fact, even if great fragmentation still persists in most countries, the size and corresponding economic strength of companies is becoming crucial for balancing the increasing bargaining power of retailers and achieving the minimum “critical mass” in terms of production volumes.

## **1.5 The importance of food safety in FDM processing**

As well as environmental considerations, there are other legal requirements and prohibitions which must be considered when identifying “best available techniques” in the FDM industry. There are specific requirements relating to, e.g. food safety, and these are updated from time to time. All FDM production installations, regardless of their size, geographical location or point in the production process, must comply with the required food safety standards.

The achievement of the required standards can be made easier if all of the operators with responsibilities collaborate closely. The FDM industry has identified five key areas that can ensure day-to-day food safety, i.e. improved food safety systems, traceability, crisis management, risk identification and communication. The application of such principles can also be considered with respect to environmental protection. Where quality management systems developed from, e.g. ISO 9001 *Quality System – Model for quality assurance in design/development, production, installation and servicing*, and ISO 9002 *Quality System – Model for quality assurance in production, installation and servicing*, exist, the familiarity with such systems may facilitate the use of equivalent environmental standards-related systems.

The food safety laws may have an influence on environmental considerations. For example, food safety and hygiene requirements may affect the requirement for water use to clean the equipment and the installation, making it necessary to use hot water, so there are also energy considerations. Likewise, waste water is contaminated by substances used for hygiene purposes, for cleaning and sterilisation, e.g. during the production and packaging of long-life FDM products. These issues have to be considered to ensure that hygiene standards are maintained, but taking into account the control of water, energy, and detergent and sterilant use.

Care has been taken to ensure that nothing in this document conflicts with relevant food safety legislation.

## 1.6 Legislative framework for food, drink and milk products

Protection of the consumer and of the environment, and the elimination of obstacles to the free movement of goods are among the main concerns of EU-15 FDM legislation. The EU-15 legislative framework is based on horizontal measures across product categories as well as on commodity-specific so-called vertical measures, derived from the agricultural policy or the agri-monetary system.

As well as the general legislation, e.g. financial, environmental, health and safety, the FDM sector is also controlled by specific very detailed and comprehensive legislation starting at the farm gate and ending on the dinner plate. This legislation covers the following main areas:

- food and feed safety (contaminants, pesticide residues, quality of water intended for food consumption, official control of foodstuffs, materials in contact with foodstuffs)
- food and feed hygiene (general rules, health rules concerning foodstuffs of animal origin)
- food and feed composition (additives, flavourings, processing aids, GMOs)
- consumer information (general labelling rules, quantitative ingredient declaration, lot identification, unit pricing)
- food and feed nutrition, food and feed labelling
- ionisation
- organic production.

Section 1.7 refers to some selected legislation on the environment. Other pieces of environmental legislation are also valid for the industry, e.g. 98/83/EC Directive on the quality of water for human consumption.

## 1.7 The FDM sector and the environment

The FDM sector often depends on the quality of natural resources, especially that of land and water, so preserving the environment in which the raw materials are grown is very important.

The level of pollution in waste water and the amount of waste produced by the industry can represent a significant load in some countries or regions. While most emissions from the industry are biodegradable, some sectors use materials such as salt or brine which are resistant to conventional treatment methods and can introduce, e.g. pesticide residues used on the source crop.

Traditionally, in many European countries, the sector has not been heavily regulated by environmental legislation. The impetus for the sector to improve its environmental performance has therefore been based on efficiency improvements, e.g. maximising the utilisation of materials, which subsequently leads to a minimisation of waste.

There is now a trend towards focusing on proactive environmental management systems, natural resource conservation and the performance of waste minimisation techniques. To ensure sustainability, the effects of the raw material supply, food processing, transport, distribution, preparation, and disposal must be considered and controlled. Both primary production and processing are critically dependent upon a reliable water supply and adequate water quality, in conformity with legal requirements.

It is a challenge for the FDM sector to comply with the requirements of the Packaging Directive 94/62/EC by preventing the production of packaging waste, by re-use and recycling, as well as recovering packaging waste. Packaging is essential for preservation and for protection against handling, spoilage and contamination during production, distribution and sale. It is also a marketing and sales tool and it conveys information like ingredients, nutrient content, cooking instructions and storage information.

The efficient management of packaging and the minimisation of packaging waste is the responsibility of the FDM sector as well as farmers, retailers and consumers. In this context, the CEN standards on packaging, e.g. EN 13427:2000 [195, CEN, 2000], EN 13428:2000 [196, CEN, 2000] and EN 13431:2000 [197, CEN, 2000], are very useful. These standards provide guidelines to operators to enable them to comply with the essential requirements laid down by the Packaging Directive 94/62/EC. They offer the required flexibility to encourage innovation and enable packaging to be adapted to consumer needs. They can also be incorporated into the environmental and quality management systems within companies.

EMSs involve developing policies and guidelines, establishing objectives and programmes, allocating environmental responsibilities within an organisational structure, training and communication activities, operational control and conducting surveys and audits.

Many FDM companies have implemented an EMS and some are certified or in the process of being certified to ISO 14001 or the EU-15 Eco-Management and Audit Scheme (EMAS). In 2003, the FDM sector had the highest number of EMAS registered organisations in any sector and represented 9% of all EMAS registered organisations (for further information see Section 4.1.1).

### 1.7.1 Key environmental issues

Water consumption is one of the key environmental issues for the FDM sector. Most of the water which is not used as an ingredient, ultimately appears in the waste water stream. Typically, untreated FDM waste water is high in both COD and BOD. Levels can be 10 - 100 times higher than in domestic waste water. The SS concentration varies from negligible to as high as 120000 mg/l. Untreated waste water from some sectors, e.g. meat, fish, dairy and vegetable oil production, contains high concentrations of FOG.

The main air pollutants from FDM processes are dust, VOCs and odour. Refrigerants containing ammonia and halogen may be accidentally released. Odour is a local problem either related to the process or to the storage of raw materials, by-products or waste.

Noise may also be a problem for some installations, typically associated with vehicle movements and refrigeration.

The solid output from FDM installations is composed of by-products, co-products and waste. The main sources of solid output are spillage, leakage, overflow, defects/returned products, inherent loss, retained material that cannot freely drain to the next stage in the process and heat deposited waste.

The FDM sector is dependent on energy for processes required for freshness and food safety. Mechanical processing, e.g. raw material preparation and sizing, and thermal processing, e.g. dehydration, are the most commonly used techniques for food preservation and processing. Both require significant amounts of energy. Process heating uses approximately 29 % of the total energy used in the FDM sector. Process cooling and refrigeration accounts for about 16 % of the total energy used.

Table 1.6 shows the key environmental issues for some FDM sectors.

|                          | Water use | Waste water | Chemicals use | Air pollution | Noise | Odour | Solid output | Energy use |                           |
|--------------------------|-----------|-------------|---------------|---------------|-------|-------|--------------|------------|---------------------------|
|                          |           |             |               |               |       |       |              | Heating    | Cooling and refrigeration |
| Meat and poultry         | yes       | yes         |               | yes           |       | yes   | yes          | yes        | yes                       |
| Fish and shellfish       | yes       | yes         |               |               | yes   | yes   | yes          | yes        | yes                       |
| Fruit and vegetables     | yes       | yes         |               |               |       |       | yes          | yes        | yes                       |
| Vegetable oils and fats  | yes       | yes         | yes           | yes           |       | yes   | yes          | yes        | yes                       |
| Dairy products           |           | yes         | yes           | yes           | yes   | yes   | yes          | yes        | yes                       |
| Dry pasta                | yes       |             |               | yes           |       |       |              | yes        |                           |
| Starch                   | yes       | yes         |               | yes           |       |       | yes          | yes        |                           |
| Sugar                    | yes       | yes         |               |               |       |       | yes          | yes        |                           |
| Drinks                   | yes       | yes         |               |               |       |       | yes          | yes        | yes                       |
| Breweries                | yes       | yes         |               | yes           | yes   | yes   | yes          | yes        | yes                       |
| Citric acid fermentation | yes       | yes         |               |               |       |       | yes          | yes        |                           |

This table shows the key environmental issues for each sector and does not represent comparative quantitative data

**Table 1.6: Environmental issues for some FDM sectors**



## 2 APPLIED PROCESSES AND TECHNIQUES

Manufacturing in the FDM sector is diverse, using numerous individual processes. There are huge variations even in the production of similar products. All processes used in the sector cannot be described in detail in this document, but it covers a very wide range from the whole sector. Section 2.1 provides a short description of the processing techniques and unit operations used in the FDM sector, including their objectives and field of application. The application of processing techniques and unit operations in some FDM sectors is described in Section 2.2. The main environmental issues are listed, together with consumption and emission data, in Chapter 3.

### 2.1 Processing techniques and unit operations

The most commonly used processing techniques and unit operations in the FDM sector are shown in Table 2.1.

| <b>A. Materials reception and preparation</b> |   |
|---|---|
| A.1   | Materials handling and storage  |
| A.2   | Sorting/screening, grading, dehulling, destemming/destalking and trimming |
| A.3   | Peeling   |
| A.4   | Washing   |
| A.5   | Thawing   |
| <b>B. Size reduction, mixing and forming</b>  |   |
| B.1   | Cutting, slicing, chopping, mincing, pulping and pressing                 |
| B.2   | Mixing/blending, homogenisation and conching                              |
| B.3   | Grinding/milling and crushing   |
| B.4   | Forming/moulding and extruding  |
| <b>C. Separation techniques</b>               |   |
| C.1   | Extraction  |
| C.2   | Deionisation  |
| C.3   | Fining  |
| C.4   | Centrifugation and sedimentation  |
| C.5   | Filtration  |
| C.6   | Membrane separation   |
| C.7   | Crystallisation   |
| C.8   | Removal of free fatty acids by neutralisation                             |
| C.9   | Bleaching   |
| C.10  | Deodorisation by steam stripping  |
| C.11  | Decolourisation   |
| C.12  | Distillation  |
| <b>D. Product processing technology</b>       |   |
| D.1   | Soaking   |
| D.2   | Dissolving  |
| D.3   | Solubilisation/alkalising   |
| D.4   | Fermentation  |
| D.5   | Coagulation   |
| D.6   | Germination   |
| D.7   | Brining/curing and pickling   |
| D.8   | Smoking   |
| D.9   | Hardening   |
| D.10  | Sulphitation  |
| D.11  | Carbonatation   |
| D.12  | Carbonation   |
| D.13  | Coating/spraying/enrobing/agglomeration/encapsulation                     |
| D.14  | Ageing  |

| <b>E. Heat processing</b>               |  |
|---|--|
| E.1                                     | Melting                                  |
| E.2                                     | Blanching                                |
| E.3                                     | Cooking and boiling                      |
| E.4                                     | Baking                                   |
| E.5                                     | Roasting                                 |
| E.6                                     | Frying                                   |
| E.7                                     | Tempering                                |
| E.8                                     | Pasteurisation, sterilisation and UHT    |
| <b>F. Concentration by heat</b>         |  |
| F.1                                     | Evaporation (liquid to liquid)           |
| F.2                                     | Drying (liquid to solid)                 |
| F.3                                     | Dehydration (solid to solid)             |
| <b>G. Processing by removal of heat</b> |  |
| G.1                                     | Cooling, chilling and cold stabilisation |
| G.2                                     | Freezing                                 |
| G.3                                     | Freeze-drying/lyophilisation             |
| <b>H. Post processing operations</b>    |  |
| H.1                                     | Packing and filling                      |
| H.2                                     | Gas flushing and storage under gas       |
| <b>U. Utility processes</b>             |  |
| U.1                                     | Cleaning and disinfection                |
| U.2                                     | Energy generation and consumption        |
| U.3                                     | Water use                                |
| U.4                                     | Vacuum generation                        |
| U.5                                     | Refrigeration                            |
| U.6                                     | Compressed air generation                |

**Table 2.1: The processing techniques and unit operations most commonly used in the FDM sector [1, CIAA, 2002]**

The raw materials used by the FDM sector are natural products, which may vary from season to season and from year to year. It may, therefore, be necessary to adapt production processes to accommodate the changes in characteristics of the raw materials.

To process a raw material into a product normally involves applying a range of processing techniques linked together into a production line.

## **2.1.1 Materials reception and preparation (A)**

### **2.1.1.1 Materials handling and storage (A.1)**

#### **2.1.1.1.1 Objective**

Materials handling applies to the receipt, unpacking, storage and internal conveying of raw materials, intermediate products, final products and other outputs, including waste.

#### **2.1.1.1.2 Field of application**

Applied in all FDM premises.

### 2.1.1.1.3 Description of techniques, methods and equipment

Solid materials are commonly delivered in bags stacked on pallets or in containers. They may also be delivered frozen, packed in standardised blocks with carton linings. They are typically transported by forklift trucks and stored in warehouses. Larger amounts of solid raw materials and powders are mostly delivered in bulk. These are off-loaded directly for processing or stored in silos for future use. Solid raw materials can be conveyed by water, e.g. as is often the case for vegetables, roots and tubers, by air, e.g. as is the case for solid particles and powder, or by conveyor belts, elevators, screw conveyors and pumps.

Liquid materials are usually delivered in bulk tankers and then pumped into storage tanks. The internal transport of liquid is achieved by pumping the liquid through pipework systems, which can be extensive and complex. Smaller quantities of liquids are also delivered in mini-bulk containers or in drums. These are then transported to storage areas by forklift trucks.

Gases like N<sub>2</sub>, CO<sub>2</sub> and SO<sub>2</sub> are delivered and stored in special pressurised containers. When they are required they are connected to the system concerned and transported through the pipework system by pressure differences. For example, SO<sub>2</sub> is used in the processing of sugar and wine, and N<sub>2</sub> and CO<sub>2</sub> in packing and chilling.

### 2.1.1.2 Sorting/screening, grading, dehulling, destemming/destalking and trimming (A.2)

#### 2.1.1.2.1 Objective

Most raw materials contain some components which are inedible or have variable physical characteristics. Processing techniques such as sorting or screening, grading, dehulling, destemming or destalking and trimming are necessary to obtain the required uniformity of the raw material for further processing. A metal detector may also be used to ensure any metal particles in the raw material are removed.

#### 2.1.1.2.2 Field of application

These processing techniques are used as a first step in the processing of fruit and vegetables. They are also used for meat, egg and fish processing.

#### 2.1.1.2.3 Description of techniques, methods and equipment

Dry and wet **sorting or screening** is the separation of raw materials and/or slurries into categories on the basis of shape, size, weight, image and colour. Dry sorting is applied in the malting industry to select even sized grains. Wet sorting is used for slurries, to separate components.

Size sorting and dry cleaning of agricultural raw materials separates solids into two or more fractions. Size sorting is especially important for FDM products which have to be heated or cooled, as large differences in size can lead to an over or under-processing of the product. For size sorting, various types of screens and sieves, with fixed or variable apertures, can be used. The screens may be stationary, rotating or vibrating. Shape sorting can be carried out manually or mechanically with, e.g. a belt- or roller-sorter. Weight sorting is a very accurate method and is, therefore, used for more valuable foods, e.g. for cut meats, eggs, tropical fruits and certain vegetables. Image processing is used to sort foods on the basis of length, diameter and appearance, i.e. surface defects and orientation of food on a conveyor. Finally, colour sorting of defective discoloured items, can be applied at high rates using microprocessor controlled colour sorters.

Sorting also allows the separation of some additional undesirable material at first sight, e.g. leaves and stones, or inappropriate raw material such as immature or rotten berries, and is aimed at ensuring that only good quality food is preserved and passed on for further processing.

**Grading** is the assessment of a number of food characteristics to obtain an indication of their overall quality. The technique is normally carried out by trained operators. Meats, e.g. are examined by inspectors for disease, fat distribution, carcase size and shape. Other graded products include cheese and tea. In some cases, grading is based on laboratory analysis results.

In the wine industry, grading covers the necessary classification of the grapes harvested according to their degree of maturity, e.g. sugar content. Many characteristics cannot be examined automatically and trained operators are employed to simultaneously assess several characteristics to produce a uniform high quality product. Grading is more expensive than sorting due to the high costs of the skilled personnel required.

**Dehulling** is the removal of hulls from vegetables and shells from cocoa beans. To remove the shells from cocoa beans, the beans are first broken between adjustable toothed rollers. The broken pieces are subsequently separated in fractions by sieving. Each fraction is treated with a stream of air that carries the light shell pieces away. This breaking and fanning process is often referred to as winnowing.

Dehulling is also used in soybean crushing processes. The dehulling of soybeans is always preceded by a heating step, which enhances the removal of the hulls. The ease of dehulling vegetables depends on the thickness of the seed coat and can be achieved via wet or dry methods. The wet method involves soaking the vegetables in water for a few hours, draining, drying, milling and then blowing them with air to remove the seed coat. In the dry method, oil is mixed with the seeds by passing them through emery-coated rollers to abrade the surface. This is common practice for vegetables with particularly tough seed coats.

**Destemming or destalking** is the removal of fruit and vegetable stems, e.g. grapes. It is used for winemaking.

**Trimming** is used for the removal of either inedible parts or parts with defects, or for cutting the raw material to a size that is suitable for further processing. Trimming can be carried out manually or by rotating knives.

### **2.1.1.3 Peeling (A.3)**

#### **2.1.1.3.1 Objective**

The objective of peeling is to remove the skin/peel from raw fruit and vegetables. This improves the appearance and taste of the final product. During peeling, the losses need to be minimised by removing as little of the underlying food as possible but still achieving a clean peeled surface.

#### **2.1.1.3.2 Field of application**

Peeling is applied on an industrial scale to fruits, vegetables, roots, tubers and potatoes.

#### **2.1.1.3.3 Description of techniques, methods and equipment**

Various methods for peeling are steam peeling, knife peeling, abrasion peeling, caustic peeling and flame peeling. These techniques are described in Sections 4.7.3.4 to 4.7.3.4.7 inclusive.

### **2.1.1.4 Washing (A.4)**

#### **2.1.1.4.1 Objective**

This section applies to washing the FDM materials only and not cleaning the equipment or the process installation. The objective of washing is to remove and separate unwanted components to ensure that the surface of the food is in a suitable condition for further processing. Unwanted components can include dirt or residual peel, brine used for preservation, soil, micro-organisms, pesticide residues and salts.

#### **2.1.1.4.2 Field of application**

Washing is widely applied as a first processing step for root crops, potatoes, cereals, fruit and vegetables.

#### **2.1.1.4.3 Description of techniques, methods and equipment**

There are many types of machines and systems that have been adapted for washing material. Washing can be carried out by vigorous spraying with water, or by immersion with the aid of brushes, or by shaking and stirring. Sometimes cleaning substances are added. Warm water may be used but this can accelerate chemical and microbiological spoilage unless careful control of the washing time and process is carried out.

The dirt, once loosened, usually differs so greatly from the product that the actual separation of dirt and product is normally straightforward, e.g. by sedimentation. Semi-processed vegetables may arrive at the installation in strong brines, if so, the excess salt needs to be removed by rinsing with running water.

#### **2.1.1.5 Thawing (A.5)**

##### **2.1.1.5.1 Objective**

When raw materials, i.e. fish and meat, are received frozen, thawing is needed before further processing is carried out. Thawing is sometimes called defrosting. In this document, the word defrosting is used to describe the removal of frost from the inside of a refrigerator or coldstore.

##### **2.1.1.5.2 Field of application**

Since the processing of frozen meat and fish is common, thawing is widely applied in these sectors. It is also used in some other sectors such as in the production of ready-to-eat meals.

##### **2.1.1.5.3 Description of techniques, methods and equipment**

Thawing at ambient temperatures is slow compared to using water or hot air. The latter may cause a rapid growth of micro-organisms on the surface layers of the thawed product and hinder reabsorption of thawed water. This creates the unsightly and often nutritionally wasteful drip loss. The use of microwave energy, which is not transferred by conduction through the thawed food layers, is a faster and less damaging thawing process.

The traditional thawing of meat and fish takes place under running water. In this case, the unpacked meat or fish are completely immersed in pools with water. Meat and fish can also be thawed with air at controlled temperatures. Thawing by sprinkling is also applied. Desalting and thawing are carried out simultaneously.

#### **2.1.2 Size reduction, mixing and forming (B)**

##### **2.1.2.1 Cutting, slicing, chopping, mincing, pulping and pressing (B.1)**

###### **2.1.2.1.1 Objective**

The objective of cutting, slicing, chopping, mincing, pulping and pressing is to reduce the size of material either for further processing or to improve the eating quality or suitability for direct consumption.

###### **2.1.2.1.2 Field of application**

These operations are widely applied in the FDM sector. For example, they are used in the processing of meat, fish, cheese, vegetables, fruit, potatoes, and various crops, e.g. sugar beet.

### 2.1.2.1.3 Description of techniques, methods and equipment

A large variety of equipment is available, normally adapted to the product to be processed. Equipment can be power or hand-operated, depending on the size of the operations.

**Cutting** is used for size reduction of large to medium sized materials. Knives, blades, cleavers or saws are usually used for cutting. Cutting is an important operation in meat and fish processing. The cutting of meat is used post slaughtering to dress and split carcasses, to remove offal and to remove appendages and is covered in the “Slaughterhouse and animal by-products BREF”. At meat installations, carcasses are further reduced into retail cuts of joints by the removal of bone, skin and fat. Meat prepared for further processing into, e.g. ham, bacon or sausage, is initially treated in a similar manner to fresh meat, and will then be subject to further processing operations. These may include deboning, derinding, defatting, slicing, chopping, mincing and emulsifying. The cutting equipment used in meat processing includes power operated cleavers, circular or straight saws for splitting carcasses, and band saws for the further reduction of the carcasses. These are all electrically operated. Special derinding machines are used for separating rind and fat from pork. The cutting of potatoes for the production of potato chips often involves the use of hydro cutters where the potatoes are conveyed by water at high speed over fixed blades.

**Slicing** produces pieces of material of equal thickness. Slicing equipment consists of rotating or reciprocating blades which cut the food when it passes beneath. Sometimes the material is pressed against the blades by centrifugal force. In other cases, e.g. for slicing meat products, the material is held on a carriage as it travels across the blade. Hard fruit, such as apples, are simultaneously sliced and de-cored as they are forced over stationary knives inside a tube. In the sugar industry, sugar beets are cut into thin slices, called “cossettes”.

A variant of slicing is dicing and is applied to meat, fruits and vegetables. In dicing, the food is first sliced and then cut into strips by rotating blades. The strips are passed on to a second set of rotating knives, which operate at right angles to the first set, and cut the strips into cubes.

**Chopping** breaks down raw materials into small particles. Chopping into a coarse pulp is applied to meat, fruits and vegetables. In chopping, the material is placed in a slowly rotating bowl and subjected to a set of blades rotating at high speed. This technique, also called bowl chopping, is widely used in the production of sausages and similar products. The degree of size reduction can be varied depending on the knife-speed and cutting time, and in extreme cases, the material can be reduced to an emulsion if required.

**Mincing** is mainly used for the size reduction and homogenisation of meat. A meat grinder is used to mince the meat. This is a lightly constructed screw press with a cutting plate or rotating knives at its outlet. The process is a combination of cutting and extrusion, where the meat is passed through a plate with orifices.

**Pulping** is mainly used for the size reduction and homogenisation of fruit and vegetables. A moving rough surface ruptures the fruit or vegetables and squeezes the material through a gap producing an homogenised mass. The most common pulpers are drum pulpers and disc pulpers. Sometimes the pulping process is used for juice extraction.

**Pressing** is applied to extract the liquid part of grapes, other raw materials or marc after maceration. Pressing is used in wine production, for some other alcoholic drinks and for fruit and vegetable juices.

There are two main types of press. The horizontal pneumatic press comprises an inflated pneumatic membrane located in the centre of the press. Berries are slowly pressed releasing the juice, usually known as must in wine, cider and perry making, in a tank, while the solid parts remain in the press. In a hydraulic compression vertical press, grapes are placed in a cage which contains them during the pressing. A horizontal tray presses the grapes vertically and the must which flows through the cage is collected in a tank for further processing. The grapes remain in the cage. There are also other types of presses, e.g. belt presses and horizontal presses.

## 2.1.2.2 Mixing/blending, homogenisation and conching (B.2)

### 2.1.2.2.1 Objective

The aim of this group of operations is to obtain a uniform mixture of two or more components or to obtain an even particle size distribution in a food material. This can also result in improved characteristics and eating quality.

### 2.1.2.2.2 Field of application

These operations are widely applied in almost all FDM sectors.

### 2.1.2.2.3 Description of techniques, methods and equipment

**Mixing or blending** is the combination of different materials. The spatial distribution of the separate components are reduced to obtain a certain degree of homogeneity. Various mixing operations can be distinguished in the FDM sector.

Mixing solids with solids is carried out, e.g. during the production of animal feed, blends of tea and coffee, dried soup, cake mixes, custard, ice-cream mixes and malt blends. Mixing equipment commonly used includes rotating drums, rotary mixers, paddle and ribbon mixers and mixing screws in cylindrical or cone-shaped vessels and variable speed drive screws. Generally, cyclones are used as an integral part of the process to recover dust from the extracted air. The recovered material is then reprocessed.

Mixing solid with liquid is carried out, e.g. during the production of canned foods and dairy products. This type of mixing is also used in, e.g. the production of chocolates and sweets, where the ingredients are mixed in a more or less liquid state and solidify on cooling. For viscous mixtures, kneading machines are used. For low viscosity mixtures various types of stirrers, impellers and agitators are used.

Mixing liquid with liquid is carried out, e.g. during the production of emulsions like mayonnaise, margarine and mixtures of solutions. This type of mixing is also used to blend different wines or mineral waters with each other or with additives or extra ingredients. Various types of stirrers, impellers and agitators are used.

Finally, mixing liquid with gas is carried out, e.g. when making ice-cream, whipped cream and some sweets. During spray drying, the liquid-phase is mixed in a stream of gas. Atomisers are used to produce small liquid droplets, which are brought into contact with a stream of gas. When making ice-cream, whipped cream or a foam, small gas bubbles are fed into a liquid.

The aim of **homogenisation** is to attain a more even particle size or a more homogeneous blend of materials. It is, e.g. applied to whole milk to reduce the size of fat globules so that they stay evenly divided in the milk, thereby preventing the fat separating and the cream rising. The liquid, i.e. whole milk, is pressed under high pressure, 200 to 300 bar, through a small orifice.

**Conching** is a special method of kneading used in the chocolate industry. The molten chocolate mass is placed in a special trough-shaped vessel and is kneaded by a granite roller moving slowly back and forth. The aim of conching is to reduce the viscosity of the mass and to improve the flavour and the texture.

### 2.1.2.3 Grinding/milling and crushing (B.3)

#### 2.1.2.3.1 Objective

**Grinding or milling** is used for the size reduction of solid dry material. It may also improve the eating quality and/or suitability of the material for further processing. It is the main process in the cereal and animal feed industry and is also used to crush cane sugar and to facilitate the extraction of sugar in sugar and rum factories. **Crushing** covers, for instance, breaking the skin of berries and grapes to liberate the must.

#### 2.1.2.3.2 Field of application

**Grinding or milling** is applied where dry solid materials are processed, e.g. in the flour milling, animal feed, semolina, brewing, sugar and dairy sectors. **Crushing** is necessary to facilitate the yeasts' multiplication and also to conduct traditional macerations before pressing, e.g. in winemaking.

#### 2.1.2.3.3 Description of processing techniques, methods and equipment

A whole range of **grinding or milling** techniques and equipment are available for application with different types of food. It can be carried out dry or wet. In wet grinding or milling, smaller particle sizes can be attained. Often the dry technique is combined with sieving or air classification, which results in particle size fractions. Generally abatement systems, e.g. cyclones, are used as an integral part of the process, to recover dust from the extracted air. The recovered material is then reprocessed.

The common types of mills used in the FDM sector are hammer mills, ball mills, roller mills and disc mills. A hammer mill consists of a horizontal or vertical cylindrical chamber lined with a steel breaker plate and contains a high speed rotor fitted with hammers along its length. The material is broken apart by impact forces as the hammers drive it against the breaker plate. A ball mill consists of a slowly rotating horizontal steel cylinder, half filled with steel balls of 2.5 to 15 cm diameter. The final particle size depends on the speed of rotation and on the size of the balls. A roller mill consists of two or more steel rollers which revolve towards each other and pull particles of the food material through the space between the rollers, the space is known as the nip. The size of the nip can be adjusted for different food materials. A disc mill consists of either a single rotating disc in a stationary casing or two discs rotating in opposite directions. The food material passes through the adjustable gap between the disc and the casing or between the discs. Disc mills have intermeshing pins fixed onto the discs and casing. This improves the effectiveness of the milling.

### 2.1.2.4 Forming/moulding and extruding (B.4)

#### 2.1.2.4.1 Objective

**Forming or moulding** and **extruding** are operations used to achieve a specified shape for solid materials.

#### 2.1.2.4.2 Field of application

**Forming or moulding** is an operation widely applied in the production of chocolate, bread, biscuits, confectionery and pies. It is also an important process step in cheesemaking. **Extruding** is widely used in the production of meat sausages, confectionery products and starch-based snack foods.

### 2.1.2.4.3 Description of techniques, methods and equipment

In **forming or moulding**, the material is in a viscous form and is fed into the appropriate mould. As the moulding process progresses, the material becomes firmer and solidifies up to the point that it becomes a fixed shape.

**Extruding** is a continuous process of shaping. The material is kneaded under high pressure and pressed continuously through openings of the required shape. In cooking extruders, the material is also heat-treated or cooked, to solubilise starches. Extruders can contain one or two screws. The rotation of the screws transports and mixes the material and produces pressure build-up.

## 2.1.3 Separation techniques (C)

### 2.1.3.1 Extraction (C.1)

#### 2.1.3.1.1 Objective

The objective of extraction is to recover valuable soluble components from raw materials by primarily dissolving them in a liquid solvent, so that the components can be separated and recovered later from the liquid. It is not always the objective to recover one particular compound in pure form from a raw material, i.e. sometimes extraction is intended to separate all of the soluble compounds from the residue; an example of this is the extraction of coffee.

#### 2.1.3.1.2 Field of application

Extraction is widely applied in the FDM sector. For example, in the extraction of sugar from sugar beets or sugar cane, oil from oilseeds and from virgin pomace, coffee extract from coffee beans, caffeine from coffee beans and various other compounds such as proteins, pectins, vitamins, pigments, essential oils, aroma compounds and flavour compounds from many different materials.

#### 2.1.3.1.3 Description of techniques, methods and equipment

Extraction works according to the principle that soluble components can be separated from insoluble or less soluble components by dissolving them in a suitable solvent. Raw materials that are suitable for extraction may contain either solids only, solids and a solution, or solids and a liquid. Solid/liquid extraction is sometimes called leaching. When the soluble component is incorporated in a liquid, the extraction may be applied to recover the valuable soluble component. Commonly, the extract is the product or intermediate product and the residue is a waste or by-product. The efficiency of the extraction process depends on the selectivity of the solvent. Common solvents include water, organic solvents such as hexane, methylene chloride, ethyl acetate and alcohol. Supercritical CO<sub>2</sub> is used in coffee extraction.

Raw materials are usually pretreated to ensure efficient extraction of the desired compounds. For example, sugar beets and sugar cane are cut into thin slices, nuts and seeds are ground or flaked, coffee beans are roasted and ground, and tea leaves are dried and ground.

The simplest extraction method is a repeated extraction with fresh solvent called lateral flow extraction. However, this is rarely used because of the costs of the solvent and because it results in a very low concentration extract. The most common method used is countercurrent extraction, either in a batch or continuous process. Batch wise countercurrent extraction is normally only used for the processing of small amounts of material. In continuously operating extractors, the solid material and the solvent flow countercurrently. One difficulty with extraction is the recovery of the extracted material from the solvent. This can be carried out by evaporation, crystallisation, distillation or steam stripping.

In principle, many different methods of transport are possible for material and liquid flows. Some examples of transport systems commonly used include perforated trays connected to an unbroken conveyor or loop, moving horizontally or vertically; screw conveyors which transport the solid material in a countercurrent flow vertically or upwards under an incline slope, the screws are perforated to obtain a uniform flow of liquid and finally, an unbroken perforated belt where the solvent is circulated under pump action and sprayed on top of the solid material.

### **2.1.3.2 Deionisation (C.2)**

#### **2.1.3.2.1 Objective**

Deionisation or ion exchange is used to remove unwanted organic and/or inorganic constituents from water and food products. See also electro dialysis in Section 2.1.3.6.

#### **2.1.3.2.2 Field of application**

In the dairy industry, deionisation is applied in whey processing. For the application of whey solids in human food and in baby food, low levels of mineral constituents are required. Deionisation is also widely used in the FDM sector for the treatment of boiler feed-water for power and steam generation and for the production of deionised process water. Deionisation is also applied to remove minor ionised organic substances.

#### **2.1.3.2.3 Description of techniques, methods and equipment**

Deionisation is normally carried out by passing the product through a column containing ion exchange resin beads. The beads contain a large number of active sites which are capable of holding a wide variety of metals, non-metal inorganic molecules and ionised organic constituents. The columns are operated batch wise and need to be regenerated when the beads are exhausted or saturated. This is normally carried out by treatment of the columns and beads with a variety of chemicals which remove the impurities and regenerate the active sites.

### **2.1.3.3 Fining (C.3)**

#### **2.1.3.3.1 Objective**

Fining is the process of clarifying liquids, i.e. removing suspended particles which give the liquid a cloudy appearance.

#### **2.1.3.3.2 Field of application**

The production of sparkling wines and beer.

#### **2.1.3.3.3 Description of techniques, methods and equipment**

The fining agent introduced causes the minute hazy particles to flocculate and precipitate out of solution. These particles are proteins, polysides, polyphenols, ferrous or cupreous complexes. For the fining action to take place, the electrical charges between the fining agent and the particles must be opposed, which means that it is necessary to carefully choose the fining agent depending on the effect sought. The nature and the dose of the fining agent can be determined by laboratory tests. Moreover, some other treatments can be technically classed as examples of the fining process, such as iron elimination with potassium ferrocyanide.

The fining agents used can be divided into two major groups; organic and mineral fining agents. Some organic fining agents are gelatine, ichthyocolla, egg albumin, blood albumin, algein, caseins and caseinates. Some mineral fining agents are bentonites, silica gel and oenological tannins.

### 2.1.3.4 Centrifugation and sedimentation (C.4)

#### 2.1.3.4.1 Objective

Centrifugation and sedimentation are used to separate immiscible liquids and solids from liquids. Separation is carried out by the application of either centrifugal forces or natural gravity.

#### 2.1.3.4.2 Field of application

Typically used in the dairy industry in the clarification of milk, the skimming of milk and whey, the concentration of cream, the production and recovery of casein, in the cheese industry, and in lactose and whey protein processing. It is also used in drink technology, vegetable and fruit juices, coffee, tea, beer, wine, soy milk, oil and fat processing/recovery, cocoa butter manufacturing, sugar manufacturing and waste water treatment.

#### 2.1.3.4.3 Description of techniques, methods and equipment

When the differences in density are large and time is not a limiting factor, natural gravity is applied. This process is called **sedimentation** and can be batch wise or continuous. The batch wise process occurs in a vessel containing a dispersion of solid particles with a higher density than the liquid. In time, these heavier particles fall to the bottom of the vessel. If the height of the vessel is shortened and the surface increased, the sedimentation time can be reduced. In the continuous process, the liquid containing the slurried particles is introduced at one end of the process and flows towards an overflow. The sedimentation capacity of the vessel can be increased by adding horizontal or inclined baffle plates.

**Centrifugation** is used to separate mixtures of two or more phases, one of which is a continuous phase. There are two general ways to operate centrifuges. Continuous systems and systems with breaks for cleaning. In continuous systems, the sludge can be discharged during the process. The driving force behind the separation is the difference in density between the phases. By using centrifugal forces, the separation process is accelerated. The necessary centrifugal forces are generated by rotating the materials. The force generated depends on the speed and radius of rotation. In raw milk, e.g. the skimmed milk is the continuous phase, the fat phase is a discontinuous phase formed of fat globules with diameters of some microns, and a third phase consists of solid particles. In beer production, clarification of the hot wort is carried out to remove hot trub particles to get a clear wort. The commonly used equipment for wort clarification is the hydrocyclone, where wort trub particles are separated in tangential flow.

Centrifuges are classified into four groups:

- tubular and disc bowl centrifuges
- solid bowl and nozzle or valve discharge centrifuges
- conveyor bowl, reciprocating conveyor and basket centrifuges
- hydrocyclones or whirlpools.

A tubular bowl centrifuge consists of a vertical cylinder, which rotates at 15000 to 50000 rpm, inside a stationary casing. It is used to separate immiscible liquids, e.g. vegetable oil and water or solids from liquid. The two components are separated into annular layers, with the denser liquid or solid setting nearer to the bowl wall. The two layers are then discharged separately. Typically, the disc bowl centrifuge is more widely used in the FDM sector as it can achieve a better separation due to the thinner layers of liquid formed. The cylindrical bowl contains inverted cones or discs and the liquids only have to travel a short distance to achieve separation. These centrifuges operate at 2000 to 7000 rpm and have capacities of up to 150000 l/h. Disc bowl centrifuges are used to separate cream from milk; to clarify oils, coffee extracts and juices or to separate starch from slurry.

A solid bowl centrifuge is the simplest solids/liquid centrifuge and is useful when small amounts of solids must be removed from large volumes of liquid. It consists of a rotating cylindrical bowl. Liquor is fed into the bowl; the solids settle out against the bowl wall whilst the liquid spills over the top of the bowl. Cakes can also be removed without stopping the centrifuge. Liquors containing higher levels of solids, i.e. >3 % w/w, can be separated using nozzle or valve discharge centrifuges. These centrifuges are a modified disc bowl centrifuge with a double conical bowl which enables the automatic discharge of solids. These types of centrifuges are used to treat oils, juices, beers and starches to recover solid parts, e.g. yeast cells. They have capacities of up to 300000 l/h. A special type is the bactofuge, which is a high speed centrifugal process which separates bacterial cells and spores from milk.

The conveyor bowl or decanter, reciprocating conveyor and basket centrifuges are used when the feed contains high levels of solids or sludges. They are used to recover animal protein, e.g. precipitated casein from skimmed milk, vegetable proteins, to separate coffee, cocoa and tea slurries and to remove sludge from oils. In the conveyor bowl centrifuge, the solid bowl rotates at 25 rpm faster than the screw conveyor. This causes the solids to be conveyed to one end of the centrifuge whereas the liquid fraction moves to the other larger diameter end. The reciprocating conveyor centrifuge is used to separate fragile solids, e.g. crystals from liquor.

The feed enters a rotating basket through a funnel, which rotates at the same speed. This gradually accelerates the liquid to the bowl speed and thus minimises shear forces. Liquid passes through perforations in the bowl wall. When the layer of solids has built up, it is pushed forward by a reciprocating arm. The basket centrifuge has a perforated basket lined with a filtering medium, which rotates at 2000 rpm. Separation occurs in cycles, which last from 5 to 30 minutes. In the three stages of the cycle, the feed liquor first enters the slowly rotating bowl, the speed is then increased and separation takes place, finally the speed of the bowl is reduced and the cake is discharged through the base. Capacities are up to 90000 l/h.

A typical hydrocyclone comprises a conical section terminating in a cylindrical section. The hydrocyclone is fitted with a tangential inlet and closed with an end plate, with an axially mounted overflow pipe or vortex finder. The end of the conical portion terminates in a circular apex opening. During operation, the slurry is forced, under pump pressure, through the tangential inlet and this produces a strong swirling motion. The fraction of the slurry contains the lighter particles discharged through the overflow, and the remaining slurry and solids are discharged through the underflow opening.

### 2.1.3.5 Filtration (C.5)

#### 2.1.3.5.1 Objective

Filtration is the separation of solids from a suspension in a liquid by means of a porous medium, screen or filter cloth, which retains the solids and allows the liquid to pass through. Air filtration is discussed in Sections 4.4.3.7.1, 4.4.3.7.2 and 4.4.3.7.3.

#### 2.1.3.5.2 Field of application

Filtration is used in the FDM sector to clarify liquid products by the removal of small amounts of solid particles with the subsequent recovery of the filtrate, e.g. for wine, beer, oils and syrups, and to separate a liquid from a significant quantity of solid material to obtain the filtrate or cake, or both, e.g. for fruit juices or beer.

#### 2.1.3.5.3 Description of techniques, methods and equipment

The technique operates either by **pressure filtration**, i.e. applying pressure to the feed side, or by **vacuum filtration**, i.e. applying a vacuum to the filtrate side.

The two main types of **pressure filtration** are the plate and frame filter press and the leaf filter.

The plate and frame filter press consists of plates and frames arranged alternately and supported on a pair of rails. The hollow frame is separated from the plate by the filter cloth. The slurry is pumped through a port in each frame and the filtrate passes through the cloth and flows down the grooved surfaces of the plates and is drained through an outlet channel in the base of each plate. The filter operates at a pressure of between 250 to 800 kPa. The filter press is operated batch wise; the optimum cycle time depends on the resistance offered by the filter cake and the time taken to dismantle and refit the press. This press can be used when the dismantling, emptying and refitting of the presses are carried out in a semi-automatic manner. Sometimes, filter aids such as perlite or diatomaceous earth are used as a pre-coat or body feed to improve the filtration. The equipment is reliable and easily maintained, and is widely used, particularly for the production of apple juice and cider and in edible oil refining. A special type of plate and frame filter press is the membrane filter press. A membrane is mounted onto the plate which can be pressurised with air or water. Due to the higher pressure on the filter cake, up to 20 bar, more liquid is recovered resulting in a dryer filter cake.

The need to develop much larger capacity units led to the introduction of the leaf filters. These consist of mesh leaves which are coated in filter medium and supported on a hollow frame, which forms the outlet channel for the filtrate. The leaves can be stacked horizontally or vertically. Feed liquor is pumped into the shell at a pressure of approximately 400 kPa. When the filtration is completed, the solid residue is blown or washed from the leaves.

**Vacuum filters** are normally operated continuously. Liquor is sucked through the filter plate or cloth and the solids are deposited on the cloth. The pressure difference on the downstream side of the filter plate is normally limited to 100 kPa due the cost of vacuum generation. Sometimes, filter aids are used as a pre-coat or body feed to improve filtration. In these cases, a knife is used to scrape off the solid residue. Two common types of vacuum filter are the rotary drum filter and the rotary vacuum disc filter.

Rotary drum filters consist of a slowly rotating cylinder, which is divided into compartments, which are themselves covered with a filter cloth and connected to a central vacuum pump. As the drum rotates, it dips into a bath of liquor. The filtrate flows through the filter cloth of the immersed compartment. When the compartment leaves the bath, the filter cake is sucked free of liquor and washed. As the drum rotates further, the vacuum is released for the compartment in question and the cake is loosened from the cloth by the application of compressed air, and then removed by means of a scraper. The same procedure occurs for each compartment in turn as the cycle is repeated.

Rotary vacuum disc filters consist of a series of vertical discs which rotate slowly in a bath of liquor in a similar cycle to drum filters. Each disc is divided into segments and each segment has an outlet to a central shaft. The discs are fitted with scrapers to continuously remove the solid residue.

### **2.1.3.6 Membrane separation (C.6)**

#### **2.1.3.6.1 Objective**

Membrane separation is aimed at the selective removal of water, solutes and/or suspended material from a solution by using semi-permeable membranes. It is considered to be a fractionation technique.

#### **2.1.3.6.2 Field of application**

Membrane separation is applied for the concentration of liquids, e.g. with cheese whey, the removal of salts from whey or water, whey fractionation, and water purification.

### 2.1.3.6.3 Description of techniques, methods and equipment

There are two membrane separation techniques used in the FDM sector, i.e. membrane separation and electro dialysis.

**Membrane separation** is a pressure driven filtration technique in which a solution is forced through a porous membrane. Some of the dissolved solids are held back because their molecular size is too large to allow them to pass through. The size range depends upon the type of membranes used. Fractionation of the feed stream occurs, with some molecules being concentrated on the upstream side of the membrane, which is known as the concentrate or retentate. The smaller molecules pass through the membrane into the permeate stream.

The various membrane separation techniques can be characterised by their membrane pore size. Cross-flow microfiltration (CMF), can be used to remove bacteria from skimmed milk, or for fractionation of the skimmed milk into a casein rich retentate and a milk serum devoid of casein; the membrane pore size ranges from about 0.1 to 5  $\mu\text{m}$ . Ultrafiltration (UF) is applied to both skimmed milk and whey, to concentrate the respective protein components; the membrane pore size ranges from about 10 to 100 nm. Nanofiltration (NF) membranes have selective permeability for minerals and some small organic and inorganic molecules and NF is used predominantly for concentration and pre-demineralisation (removal of salt) of whey; the pore sizes of the NF membrane range from about 1 to 10 nm. Reverse osmosis filtration (RO) membranes are permeable to water but not minerals and are, therefore, used for dewatering; concentration of whey or skimmed milk; or for polishing NF permeates or evaporator condensate and in water treatment, e.g. softening and salt removal; the membrane pore size ranges from about 0.1 to 1 nm.

**Electrodialysis** is a membrane separation process undertaken in the presence of an applied electro potential. Low molecular weight ions migrate to an electrical field across cationic or anionic membranes. These membranes are alternately arranged between the cathode and anode within a stack. It is principally applied in the dairy industry for the removal of salt from whey.

### 2.1.3.7 Crystallisation (C.7)

#### 2.1.3.7.1 Objective

The objective of crystallisation is to separate a solute from a solvent.

#### 2.1.3.7.2 Field of application

Crystallisation is applied in the dairy industry, where lactose is produced from cheese whey or casein whey, and the sugar industry. It is also used in the edible oil industry to modify the properties of edible oils and fats; in this case it is also called fractionation.

#### 2.1.3.7.3 Description of the technique, methods and equipment

Crystallisation is the formation of solid crystals from a solution. Crystals solidify in a definite geometric form. They are usually grown by the introduction of nuclei into a supersaturated solution. Any impurities in the liquid are usually not incorporated into the lattice structure of the desired crystal. Accordingly, crystallisation is also a purification process.

### 2.1.3.8 Removal of free fatty acids (ffa) by neutralisation (C.8)

#### 2.1.3.8.1 Objective

The objective of the chemical neutralisation process is to remove the ffa and the phosphatides from vegetable oils, using caustic and phosphoric acid or, in some cases, citric acid.

### 2.1.3.8.2 Field of application

Chemical neutralisation is applied in the refining process of vegetable oils such as soybean oil, sunflower oil, rapeseed oil, and of animal oils and fats such as tallow or fish-oil.

### 2.1.3.8.3 Description of techniques, methods and equipment

The oil is preheated using steam, after which phosphoric acid or citric acid is mixed with it to increase the water solubility of the phosphatides. The acidified oil, with a crude oil content of 0.5 to 6 %, is then mixed with a caustic solution, which neutralises both the ffa and the phosphoric or citric acid, and further increases the water solubility of the phosphatides. The aqueous mixture of soap and phosphatides, which is known as soap-stock, is separated from the oil by centrifugation. The oil is mixed with water to wash off the rest of the soaps. Again, the water is removed from the oil by centrifugation. The caustic refined oil may be dried under vacuum conditions and then pumped to a storage tank. The process is typically operated in a continuous way, as shown in Figure 2.1, but it can also be a semi-continuous or batch process, using long period mixing and sedimentation equipment.

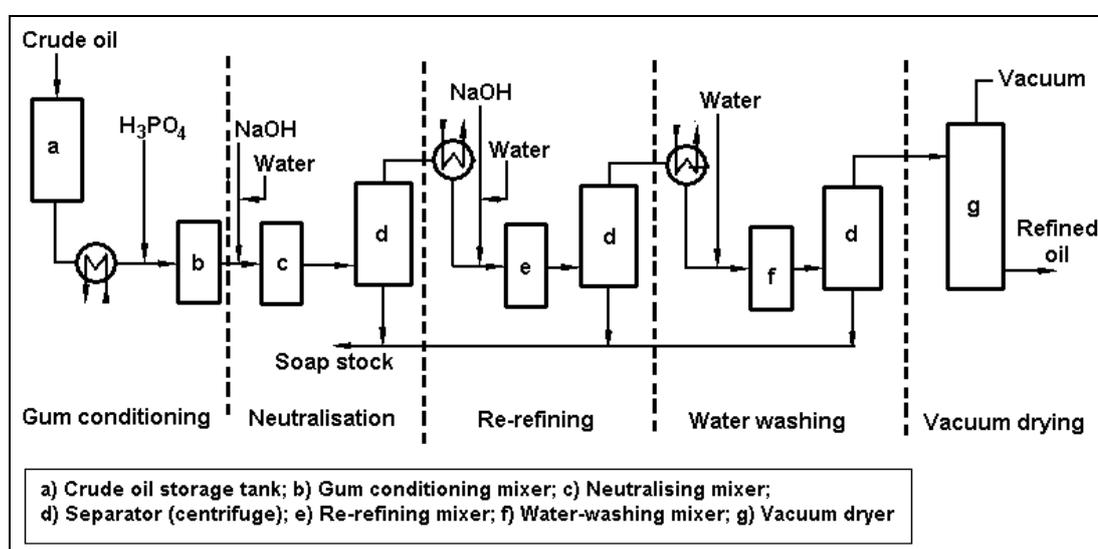


Figure 2.1: Flow diagram of continuous neutralisation of oils and fats [87, Ullmann, 2001]

The centrifuge aqueous discharges, i.e. the soap-stocks, are combined and further treated in a soap-stock splitting system. This acidulation process is used to recover the ffa after treatment with concentrated acid, usually sulphuric acid or occasionally hydrochloric acid, and heating with steam. The separated ffa are then removed in a decanter centrifuge. In integrated installations, the soap-stock can be added to the meal toasting process. The phosphatides recovered are used as lecithin in human food or in animal feed.

### 2.1.3.9 Bleaching (C.9)

#### 2.1.3.9.1 Objective

The objective of bleaching is to remove pigments, metals, e.g. nickel or iron from other oil refinery processes; residual soaps and phospholipids from the oil or fat.

#### 2.1.3.9.2 Field of application

Bleaching is applied in the refining of edible oils and fats.

### **2.1.3.9.3 Description of techniques, methods and equipment**

Edible oils and fats are mixed with bleaching earth that has an affinity for adsorbing the above-mentioned undesirable compounds. The oil is mixed under vacuum conditions with 0.1 to 3 % of bleaching earth. This is a clay mineral, such as bentonite or montmorillonite, that has been activated by thermal and/or acidic or other treatments. These earths, sometimes mixed with small amounts of activated carbon, have a very high adsorbing capacity. After bleaching for 30 to 90 minutes, the oil is separated from the bleaching earth, using filters. The spent earth contains high amounts of oil, up to 30 %. A steam stripping process can recover a part of the oil or fat. Used bleaching earth can be added to the meal in integrated installations. The bleached oil is further treated in other refinery processes. The equipment used for bleaching consists of mixing vessels, vacuum generators and filters.

### **2.1.3.10 Deodorisation by steam stripping (C.10)**

#### **2.1.3.10.1 Objective**

The objective of deodorisation is to remove ffa and other highly volatile compounds from crude degummed and/or alkali refined edible oils and fats after bleaching.

#### **2.1.3.10.2 Field of application**

Deodorising is applied in the refining of edible oils and fats.

#### **2.1.3.10.3 Description of techniques, methods and equipment**

Deodorisation is the use of steam distillation to strip ffa and other highly volatile components, under vacuum conditions, from oils and fats. The equipment used for deodorisation consists of a steam distillation column, barometric condenser, demisters and scrubbers. Steam is injected into the oil heated to over 200 °C at the bottom of the distillation column, which is under vacuum conditions. The steam strips the ffa and other impurities from the oils and fats but gums are not removed by this process. The steam is condensed afterwards, using a barometric condenser of either once-through or closed-circuit design (see Section 2.1.9.4). The separation of the volatile components from this steam can be enhanced by a one-stage or a two-stage scrubbing/condensation system and by demisters. Deodorisation can be operated in batch or continuous deodorising vessels.

### **2.1.3.11 Decolourisation (C.11)**

#### **2.1.3.11.1 Objective**

Decolourisation is carried out to improve the colour, purity, ageing, microbiological stability and shelf-life of certain food products.

#### **2.1.3.11.2 Field of application**

Decolourisation is used in the sugar, glucose, syrup and fermentation industries.

#### **2.1.3.11.3 Description of techniques, methods and equipment**

Decolourisation can be carried out by the addition of an active powder, e.g. powdered activated carbon, to the product in aqueous solution, which is then mixed under controlled conditions. Afterwards, the powder is removed by filtration, using static filters or rotary vacuum filters, while the decoloured product is processed further. This process is often carried out in multiple stages with the active material being re-used until exhausted, often using a countercurrent system.

The process can also be carried out by passing the product in aqueous solution through a column of active material, e.g. using granular activated carbon or ion exchange resin beads. Here, only minimal filtration is required after the process as the active material is held in place. Active material is withdrawn from the column at regular intervals and replaced by new or reactivated material.

The main purpose of both these operations is to remove colour molecules from the product as well as precursors that may give rise to colour formation on storage, which is known as ageing. The majority of the impurities removed are organic in nature. Passage over activated carbon may also be helpful in removing phenolic material, which may cause taints, pesticide residues and some heavy metals.

### **2.1.3.12 Distillation (C.12)**

#### **2.1.3.12.1 Objective**

Distillation is the separation of the components of a liquid mixture by partial vaporisation of the mixture and separate recovery of the vapour and residue. The more volatile components of the original mixture are obtained at a higher concentration in the vapour, the less volatile in a higher concentration in the liquid/solid residue.

#### **2.1.3.12.2 Field of application**

Distillation enables the separation and purification of volatile food products from aqueous blends. Distillation can be used to separate flavours or essential oils, but is mainly used either for the production of potable alcohol or spirits, or for the industrial production of alcohol from agricultural raw materials, e.g. fruit and grain, which can then be used in alcoholic drinks or liquors. Distillation normally follows alcoholic fermentation.

Spirit drinks production is regulated by Council Regulation (EEC) No 1576/89 [218, EC, 1989]. They are prepared from the distillate of the alcoholic yeast fermentation of products from agricultural origin.

#### **2.1.3.12.3 Description of techniques, methods and equipment**

The process takes place in two basic types of equipment; the pot still and the column still. Stills may be operated singly or in groups. The addition of heat enables the separation of alcohol/aqueous compounds from the initial liquid feed in the still. Condensed aqueous alcohol is removed as a liquid spirit from the head of the still, whilst a residual stream is discharged from the base.

The pot still can be operated in a batch or continuous manner. In the former case, a batch of material is charged to the still pot, boiling is initiated, and the vapours are then continuously removed, condensed and collected until their average composition has reached a desired value. When operated in a continuous manner, feed is continuously passed to the still pot with the vapour and liquid portions being continuously removed.

In column distillation, the alcoholic liquid or beer enters a distillation tower heated with vapour. In each contacting device, generally a tray, an equilibrium is created between the vapour enriched with volatile components and the condensed liquid. Crude alcohol is drawn off from the top of the tower and then rectified through another tower where 95 % of the alcohol is separated from higher alcohols. At the bottom of the first tower, an aqueous blend or stillage is drawn off. A condensed water or stillage water, contaminated slightly with organics, is drawn off at the bottom of the second tower once the alcohol has been dehydrated. 95 % alcohol can be turned into anhydrous alcohol by a number of different technologies. These technologies can include azeotropic distillation using a third component, adsorption by a molecular sieve, or dehydration by a membrane technique. Some spirits and ethyl alcohols of agricultural origin can be distilled higher than 84 %.

**2.1.4 Product processing technology (D)**

**2.1.4.1 Soaking (D.1)**

**2.1.4.1.1 Objective**

The objective of soaking, e.g. of vegetable seeds, such as lentils, is to moisten and soften the seeds to reduce the cooking time or to aid in seed coat removal. In the malting process, the objective of soaking is the uptake of water to activate the germination process in the kernel.

**2.1.4.1.2 Field of application**

Soaking is predominantly applied in the processing of vegetable seeds. It is also applied with grain, where the grain is soaked in the malting process prior to germination. This is often called steeping.

**2.1.4.1.3 Description of techniques, methods and equipment**

Soaking is performed by putting the vegetable seeds in water for a specified time. The time needed varies, depending on the seed variety and species and with the length of storage and storage conditions. Traditionally, dry beans are soaked for 8 to 16 hours in cold water with appropriate hardness. High temperature soaking accelerates hydration. To steep the grain, the grain is immersed in water at about 16 °C, ranging from 10 to 25 °C, depending on the equipment, the process parameters, the raw material and the finished malt to be obtained. During steeping, the moisture content increases from 12 to 15 % to anywhere between 30 to 50 %, depending again on the above conditions. During steeping, the water in the steep tanks is changed one to three times. Alternate wet and dry stages are applied. During the wet stage, the grain is aerated continuously or at intervals. During the dry stage, the grain can be aerated or the CO<sub>2</sub> can be extracted. The steeping process takes one to three days. Figure 2.2 shows an example of a steeping procedure.

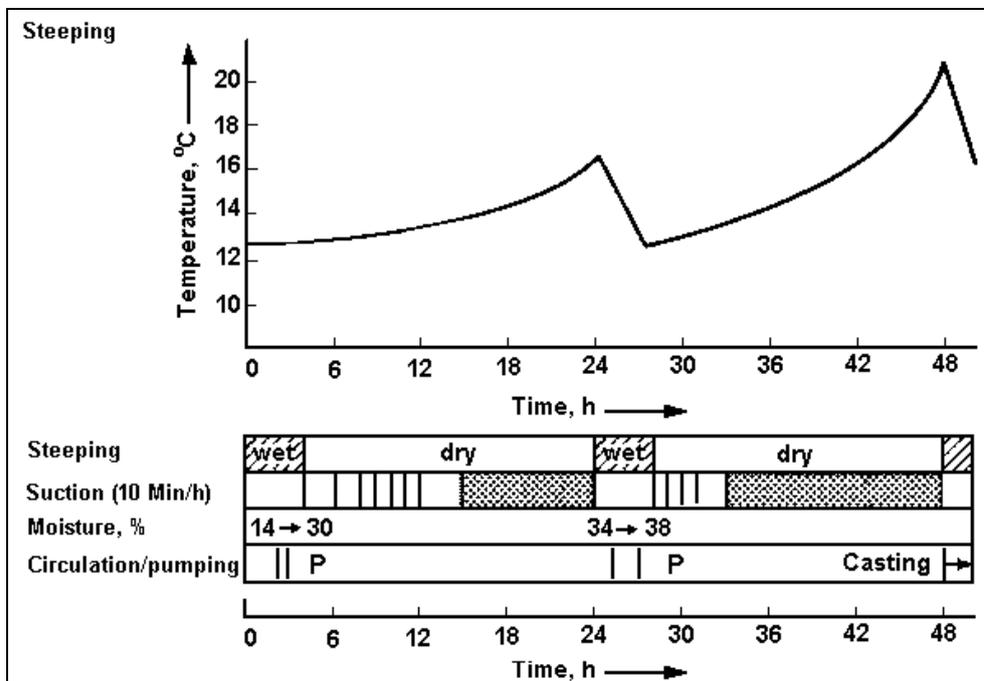


Figure 2.2: An example of the steeping procedure [87, Ullmann, 2001]

### **2.1.4.2 Dissolving (D.2)**

#### **2.1.4.2.1 Objective**

Dissolving is the addition of powder to liquid to produce solutions or suspensions for further processing.

#### **2.1.4.2.2 Field of application**

This process is used in a variety of products to recombine and reformulate them. For example, dissolving is used for recombining or reformulating milks in the dairy industry.

#### **2.1.4.2.3 Description of techniques, methods and equipment**

A variety of processes and equipment are used for this purpose. Different mixing systems may be used for the same task, ranging from simple batch dissolving tanks with efficient mixing devices, to continuous mixing processes which involve either drawing solid materials into the liquid phase or mechanical powder injection into the liquids. Depending on the product, the liquid may be at ambient or elevated temperatures.

The main types of dissolving systems are:

- a blending pump that sucks the powder into the solvent. Used for total solids of up to 25 %
- jet dissolving which uses the venturi principle to suck powder into the solvent. Used for total solids of up to 30 %
- a dissolving tank with high shear mixing impeller. Used for total solids of up to 70 %
- a dissolving tank under vacuum with high shear impeller. Used for total solids of up to 30 %.

### **2.1.4.3 Solubilisation/alkalising (D.3)**

#### **2.1.4.3.1 Objective**

Solubilisation or alkalising is the neutralisation of cocoa nibs or cocoa liquor with an alkaline solution, resulting in a darker colour and a milder taste. The milder taste is mainly the result of the neutralisation of the light acidity of fermented beans. Considerable experience and skill is required to obtain end-products with a constant colour and hue.

#### **2.1.4.3.2 Field of application**

Solubilisation is primarily used in cocoa processing.

#### **2.1.4.3.3 Description of techniques, methods and equipment**

The process is carried out by adding an alkali solution, usually potassium carbonate ( $K_2CO_3$ ), to the cocoa. Two different methods can be applied, i.e. liquid process or nibs alkalising.

In the liquid process, the liquid cocoa liquor is processed. This allows the flavour to be modified. Potash solution is added to the liquor until a pH value of 7 to 8 is achieved. The desired solubility is obtained by increasing the temperature from 45 °C up to 130 °C. Water vapour and undesirable volatile components are released to the air during the heating phase.

During nibs alkalising, green or pre-dried nibs are processed. This has the advantage of combining the drying with the nibs roasting and the disadvantage of the presence of the cocoa butter in the nibs, which may result in slight damage to the fat. Batch and continuous processes are available. Batch processes consist of a solubilisation tank at atmospheric pressure with a high shear impeller. Continuous processes take place in a reactor followed by a mixing tank, usually under vacuum. A typical batch alkalising process involves two steps. First, the nibs are

neutralised by adding the alkaline solution in a reactive vessel at atmospheric pressure. The reaction takes place within a temperature range of 80 to 105 °C. In the second step, water evaporation and nibs roasting are carried out in a FBD.

### 2.1.4.4 Fermentation (D.4)

#### 2.1.4.4.1 Objective

Fermentation is the controlled action of selected micro-organisms to alter the texture of foods, to preserve foods by the production of acids or alcohol, or to produce or modify flavours and aromas. It also preserves products by lowering the pH tolerance limits of many micro-organisms.

#### 2.1.4.4.2 Field of application

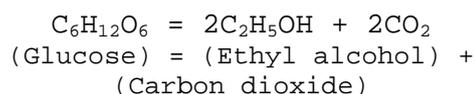
Fermentation is an important processing step for a number of FDM products. Typical applications include beer, wine, various dairy products, vegetables, meat and fish.

Alcoholic fermentation is used in beer and winemaking and for the production of spirits, mostly with cereals, grape musts, sugar juices and molasses as a raw material. Lactic acid fermentation is used for making yoghurt and other fermented dairy products, fermented meat products such as certain types of sausages and vegetables, i.e. sauerkraut. In the lactic acid fermentation of vegetables, the sliced raw material, e.g. green cabbage in the case of sauerkraut production, is salted and then fermented under anaerobic conditions.

#### 2.1.4.4.3 Description of techniques, methods and equipment

There are two types of fermentation processes, i.e. alcoholic fermentation and lactic acid fermentation.

The breakdown of simple sugars into alcohol is normally referred to as **alcoholic fermentation**. Yeasts, usually *Saccharomyces sp.*, e.g. *cerevisiae* or *bayanus*, are used to produce ethanol from carbohydrates and very small amounts of other organic compounds. This conversion can be represented by the following equation:



This is an anaerobic process, i.e. it does not require the presence of oxygen. The temperature of fermentation is usually in the range of 8 to 30 °C. The temperature affects the rate of fermentation, the efficiency of conversion and the flavour and the aroma of the finished product. The pH may also be adjusted. This ensures that the fermentation is efficient and produces the required flavour. The type of yeast species used affects the rate, efficiency, flavour and aroma and is, therefore carefully selected to give the desired results. Selected strains of yeasts are often used to optimise the alcohol yield and the production of aromatics as secondary components. Nitrogen, vitamins and trace elements are usually added as yeast nutrients. Traditionally, fermentation in beer and winemaking has been carried out in open fermentation vessels. Some have been replaced by cylindrical closed fermenters, making recovery of CO<sub>2</sub> possible.

In **lactic acid fermentation**, lactose or other sugars are converted into lactic acid and small amounts of other components. Lactic acid formation is accompanied by a decrease in pH, which is important for the taste, the aroma and the preservation of the product. There are several species of bacteria which are able to produce lactic acid. Each species gives its own typical taste and aroma. Lactic acid fermentation is an anaerobic process. It is sometimes necessary to remove as much of the oxygen as possible to enhance the fermentation process. Lactic acid fermentation is carried out at 20 to 40 °C.

To start the process, bacteria cultures known as starters are added to the raw material to be fermented. The preparation of starter cultures is a sensitive process since the risk of airborne infection must be reduced to an absolute minimum. Starter cultures must, therefore, be prepared in a separate room supplied with filtered air with a slight positive pressure compared to normal atmospheric pressure. The equipment cleaning system must also be carefully designed to prevent detergent and sterilant residues from coming into contact with the cultures and spoiling them. These very high hygiene constraints, coupled with the requirements of the temperature regulation, i.e. heat treatment of the substrate first and then cooling, require a specific energy consumption and use of cooling water.

#### **2.1.4.5 Coagulation (D.5)**

##### **2.1.4.5.1 Objective**

Coagulation is the agglomeration of suspended particles and separate solids from liquids or *vice versa*.

##### **2.1.4.5.2 Field of application**

Coagulation is used in cheese production and in the recovery of casein from milk. It is often used in milk processing to separate the curd from the whey and it is also called curdling.

##### **2.1.4.5.3 Description of technique, methods and equipment**

Temperature is one of the key factors that influence milk curdling. The required temperature is obtained by using either heat-exchangers or by direct injection of steam into the curdling vat. The temperature must be between 30 and 40 °C. Starters and other ingredients are added to the milk. These ingredients help determine the specific characteristics of the final product. Curdling is carried out in suitable vats or tanks, using either enzymatic coagulants, i.e. animal or microbial rennet or acidifying starters.

When enzymatic coagulants or acidifying starters are used, a casein jelly is formed which encloses the fat. The jelly will have different characteristics depending on which coagulant method is used. This is important for achieving the desired final production. The curd is produced by the separation of the whey, which is then gathered and sent for further processing as appropriate. To obtain further separation of the whey, e.g. to obtain a hard or semi-hard cheese, another heat treatment is given to the curd under stirring at up to 40 to 53 °C. For other kinds of cheese, such as mozzarella or provolone, as well as the curd being heated at a higher temperature, mechanical processing is also carried out to obtain the characteristic stretching/melting properties. Furthermore, organic acids are used to control the pH and to hold the curd at the right pH for the stretching properties to form.

#### **2.1.4.6 Germination (D.6)**

##### **2.1.4.6.1 Objective**

The objective of germination is to activate and develop the enzyme system in the grain kernel. This activated enzyme system is necessary to activate the starch and protein breakdown at the mashing stage before the later brewing process.

##### **2.1.4.6.2 Field of application**

Germination is an important processing step within the malting process of cereals. Malted cereals, mainly barley, are used for beer production and the production of distilled drinks, e.g. whisky. Malt is also used in food flavouring.

### 2.1.4.6.3 Description of processing techniques, methods and equipment

To start germination, the grain is steeped to obtain the necessary moisture content (see soaking, Section 2.1.4.1). The steeped grain is then transferred into germination vessels with perforated steel plate floors for pneumatic malting, or onto germination floors for floor malting. The grain is layered from about 70 to 150 cm thick for pneumatic malting and from about 5 to 15 cm for floor malting. The germination step generally lasts between 96 and 200 hours. Depending on the equipment, the process parameters, the raw material and the finished malt to be obtained, the germination process can be shorter or longer. Conditioned air, i.e. cooled or heated and humidified, is blown through the grain layer in pneumatic malting, or over it, in floor malting, to control the temperature and the moisture content during germination. To prevent the grain kernels from matting or felting, the layer of grain is turned from time to time, during which water spraying can also be applied. The germination process is stopped by drying.

### 2.1.4.7 Brining/curing and pickling (D.7)

#### 2.1.4.7.1 Objective

**Brining or curing** is a process whereby a product is treated with common salt (NaCl) and curing salts which aims for the preservation of products by lowering the  $a_w$  below microbial tolerance limits. **Pickling** is the preservation of products by lowering the pH, especially for vegetables.

The objectives of these techniques are the long-life preservation of the control of the growth of spore forming micro-organisms, a decrease in the energy needed for heat treatment, and adding taste to the product.

#### 2.1.4.7.2 Field of application

**Brining or curing** is applied in the production of certain types of cheese, meat, fish, vegetables and mushrooms. Salt levels in the product can range from 1 to 5 %. **Pickling** is applied in the fruit and vegetable sector.

#### 2.1.4.7.3 Description of techniques, methods and equipment

In the **brining or curing** of meat products, the meat is treated with common salt (NaCl) and with one or more of the following curing salts: sodium nitrate ( $\text{NaNO}_3$ ), sodium nitrite ( $\text{NaNO}_2$ ), potassium nitrate ( $\text{KNO}_3$ ) or potassium nitrite ( $\text{KNO}_2$ ). The process is designed to produce an acceptable salt level in the product of about 1 – 3 %, or a level of curing salt sufficient to produce an acceptable cured meat colour, which is produced by reaction of the meat pigment myoglobin with nitrite. Nitrite may be used or it may be derived from nitrate, which is converted to nitrite in the curing system. The presence of salt and nitrite in the product inhibit microbial growth and enhance the durability and safety of the product. Thus, salt and nitrite are essential to the curing process.

Whereas the salt content is determined by consumer acceptability, the curing salt content is controlled by law. At present, a maximum of 100 mg/kg of nitrite and 250 mg/kg of nitrate, can be contained in the finished product. Other ingredients may be added to cured meats for a number of reasons, including taste. These include polyphosphates, sugars, spices, non-meat proteins and starches. Also certain types of cheese are brined for reasons of taste and preservation.

Several methods are applied for brining or curing, i.e. dry brining/curing, injection brining/curing, immersion brining/curing and tumble/massage brining/curing.

Dry brining/curing is applied to meat and cheese. In making cured meat products, salt and other curing ingredients are deposited on the surface of the meat and are absorbed by diffusion over a period of days or even weeks. At the same time liquor diffuses out of the meat, equivalent to about 10 % of the initial meat weight. In the production of certain types of cheese, e.g. cheddar, dry salt is added to the curd.

Injection brining/curing is used in meat processing, e.g. bacon and ham. A prepared solution, i.e. brine, containing the ingredients, is injected by needle(s) into the meat, either manually or by machine, to achieve a rapid deposition of curing salts and common salt throughout the mass. After injection, the meat may be further processed or sealed in a plastic vacuum bag for a number of days, or immersed in a brine that is identical or similar in composition to the injected brine.

Immersion brining/curing is applied to cheese, meat and vegetables. During immersion, salt gradually penetrates into the product while water containing soluble product components are extracted from the product. The immersion brine may be discarded after each usage or it may be continually restrengthened and re-used with only a bleed being discharged. Water extraction by brining can range from 5 to 15 % of the product weight. The salt content of the brine ranges from 5 to 20 %.

Tumble/massage brining/curing is especially applied to meat. In this process, the movement of brine into the meat is accelerated by mechanical action. The meat may be injected with the brine before treatment or it can rely on the mechanical action, possibly assisted by vacuum, to accelerate absorption of the brine. This process is normally used when the meat is to be subsequently cooked or canned.

**Pickling** of vegetables can be carried out by adding organic acids until the pH is below 4.3. In the process of making sauerkraut, salt is added (brining/curing) to promote the growth of lactic acid bacteria, for taste reasons and for conservation.

#### **2.1.4.8 Smoking (D.8)**

##### **2.1.4.8.1 Objective**

The aim of smoking is the preservation of food by exposure to smoke, which has a bacteriostatic effect. Preservation is also achieved by the drying of the surface layers and heat effects. In addition, smoking adds flavour and, in some cases, the smoking process is used to cook the food.

##### **2.1.4.8.2 Field of application**

Smoking is commonly used in the processing of fish, cheese, meat and meat products.

##### **2.1.4.8.3 Description of techniques, methods and equipment**

There are two types of smoking, hot smoking and cold smoking. These are described in Sections 4.2.5 – 4.2.5.5.

#### **2.1.4.9 Hardening (D.9)**

##### **2.1.4.9.1 Objective**

The objective of hardening is to increase the melting point of the product and to change the solid-fat content of edible oils into edible fats.

### **2.1.4.9.2 Field of application**

Hardening is applied in the processing of edible oils for the production of margarine and other edible fats.

### **2.1.4.9.3 Description of techniques, methods and equipment**

Hardening, or hydrogenation of oils, is the process of saturating mono or poly-unsaturated fatty acids by adding hydrogen gas ( $H_2$ ) for the hydrogenation and nickel as a catalyst. Hydrogen molecules, in the presence of nickel and under special process conditions, saturate the unsaturated bonds of the fatty acids of edible oils. Neutral or bleached oil is heated to a temperature of 150 to 205 °C in the presence of a nickel catalyst, maximum 10 kg catalyst/tonne product.  $H_2$  is then added to the mixing reactor to achieve the hardening, i.e. the transformation from oil to fat. Hydrogenation is an exothermic process. After the reaction, the fats are separated from the nickel, using filter presses or other filter systems. In a minority of cases, the nickel catalyst can be re-used several times until it is deactivated. Specialised companies recycle the spent nickel. The residual nickel concentration in the fats is removed by bleaching, which produces bleaching earth contaminated with nickel. The equipment used for hardening consists of mixing vessels, reaction tanks, autoclaves and filters.

### **2.1.4.10 Sulphitation (D.10)**

#### **2.1.4.10.1 Objective**

The aim of sulphitation is to prevent either microbiological degradation, unwanted colour formation or to adjust pH.

#### **2.1.4.10.2 Field of application**

Sulphitation is applied in winemaking, potato processing and shellfish processing. It is also sometimes applied in sugar production to adjust the pH.

#### **2.1.4.10.3 Description of techniques, methods and equipment**

Sulphitation is the introduction of sulphur dioxide ( $SO_2$ ) into liquids; the quantity of  $SO_2$  which can be added is regulated. It can be introduced in various forms. First, in gaseous form, generated either by burning sulphur or from liquefied gas and direct expansion. The  $SO_2$  is drawn by a fan into an absorption column in which the liquid flows. Second, in liquid form, from liquefied gas or in sodium or potassium bisulphite solution. The  $SO_2$  may also be stored as a liquid, under approximately 5 bar, in horizontal cylindrical tanks of 25 to 50 m<sup>3</sup> capacity, from which it can then be introduced into the desired process stream. Third, in solid form, as sodium or potassium metabisulphite dissolved in the liquid to be treated.

An alternative sulphite source is ammonium bisulphite. Sodium bisulphite can also be used.

### **2.1.4.11 Carbonatation (D.11)**

#### **2.1.4.11.1 Objective**

The aim of carbonatation is to remove impurities from a solution.

#### **2.1.4.11.2 Field of application**

Applied in the sugar industry.

### 2.1.4.11.3 Description of techniques, methods and equipment

Carbonation is the introduction of the milk of lime, calcium hydroxide, and carbon dioxide gas (CO<sub>2</sub>) into a liquid to form calcium carbonate and to precipitate and remove impurities. The effect of lime and CO<sub>2</sub> is the precipitation of insoluble calcium salts, the flocculation of colloidal components, the chemical degradation of other molecules such as invert sugar and amides, and the absorption of non-sugars on precipitated calcium carbonate. Lime and CO<sub>2</sub> are normally produced in lime kilns by the thermal dissociation of limestone.

Any non-sugar components contained in the raw sugar juice after extraction from the beet, make the subsequent stages in the sugar process impossible to perform. Therefore, the raw juice must be purified to allow further processing. This is achieved by continuously adding milk of lime and carbon dioxide from the lime kiln to precipitate most of the non-sugars. The product after filtration contains the calcium carbonate and the non-sugars and is used in agriculture as a liming material to improve the structure of arable soil and to regulate soil acidity. Sugar factory lime may also be used for site recovery, e.g. filling quarry ditches, and for producing bricks or cement. For aspects relating to lime kilns, see the “Cement and lime BREF” [219, EC, 2001].

### 2.1.4.12 Carbonation (D.12)

#### 2.1.4.12.1 Objective

The aim of this process is to dissolve a quantity of carbonic gas into different products to obtain a gasified or carbonated final product. When dissolved in water, carbon dioxide (CO<sub>2</sub>), is sparingly soluble and thus, slowly released, forming bubbles that provide a characteristic mouthfeel and a unique taste when consumed. In addition to an organoleptic property, under suitable conditions, CO<sub>2</sub> has a preserving property by the inhibition of the development of harmful aerobic micro-organisms. This, however, is not a substitute for other methods used to ensure microbiological safety.

#### 2.1.4.12.2 Field of application

Carbonation is an important process step in the preparation of many soft drinks and certain types of mineral waters. It is also applied in the wine and brewing industries. In the manufacture of still wines, carbonation is used to protect the colour and increase the aroma.

### 2.1.4.12.3 Description of techniques, methods and equipment

Carbonation results from the impregnation of a liquid with CO<sub>2</sub> to form carbonic acid. The CO<sub>2</sub> was traditionally obtained from lime kilns, by heating calcium carbonate, but this has now been universally replaced in the soft drinks sector by the storage of bulk liquefied gas externally delivered by a CO<sub>2</sub> supplier. The gas is stored within pressurised insulated tanks kept at a very low temperature. In common practice, the gas tends to be generated as a by-product of fermentation or chemical processes from companies outside of the soft drinks sector.

A carbonator combines CO<sub>2</sub> gas with the liquid to be carbonated. Current carbonators can be classified into two main categories; those that carbonate water only and those that carbonate the finished product mixture of syrup and water. These are sometimes coupled with coolers, often referred to as carbo-coolers. The principal designs available are carbonators with integral coolers, draining wall heat-exchangers and carbon dioxide injectors.

In combination with this process, de-aeration, i.e. the removal of air, is vital and is usually applied to the water component in a first stage. The presence of air can create spoilage problems. CO<sub>2</sub> is sometimes used to flush out air, however, the use of mechanically de-aerated water has become more popular in recent years.

The degree of carbonation varies for each soft drink formulation, from 4 g/l in fruit drinks to 9 g/l in mixer drinks and 12 g/l in soda water. The CO<sub>2</sub> gas content is one of the smallest constituents by weight, but possibly the most important, in regard to palatability of the product. CO<sub>2</sub> is one of the very few gases suitable for providing the effervescence in soft drinks; it is non-toxic, inert, and virtually tasteless and allows for convenient bulk transportation and storage.

### **2.1.4.13 Coating/spraying/enrobing/agglomeration/encapsulation (D.13)**

#### **2.1.4.13.1 Objective**

The aim of this group of operations is to cover a food product with a layer of material to improve the eating quality, to provide a barrier to the movement of moisture and gases, or as protection against mechanical damage.

#### **2.1.4.13.2 Field of application**

**Coating**, by one of the above-mentioned techniques, is applied to confectionery, ice-cream, baked goods, snack foods, fish, poultry and potato products.

#### **2.1.4.13.3 Description of techniques, methods and equipment**

Confectionery, ice-cream and baked goods are often coated with chocolate or compound coatings containing chocolate. The principal ingredients in such coatings are fat and sugar. The fat is tempered and held at a temperature of 31 to 32 °C, resulting in a liquid coating mass. This coating is applied to the food products in the form of a single or double curtain through which the food is passed on a stainless steel wire conveyor. A pan beneath the conveyor collects the excess coating, which is then recirculated through a heater to the enrobing curtain. Products like fish, poultry and potato products are often coated with batters. A suspension of flour in water to which sugar, salt, thickening agents, flavourings and colourings are added to achieve the required characteristics of the batter. The product is passed through the batter between two submerged mesh conveyors. Coating with breadcrumbs can take place by depositing food products onto a moving bed of breadcrumbs and then passing the bed through a curtain of breadcrumbs. Other methods for coating are spraying the coating material onto the product, agglomeration of products and encapsulation of the food particles.

### **2.1.4.14 Ageing (D.14)**

#### **2.1.4.14.1 Objective**

The aim of this process is to mature the product, especially for products aged in wooden casks that allow some gas exchange between the product contained in the cask and the environment. It is also part of the legal requirements when manufacturing some products.

#### **2.1.4.14.2 Field of application**

Ageing is commonly applied to wine and brown spirits.

#### **2.1.4.14.3 Description of techniques, methods and equipment**

Ageing consists of filling wooden vessels, usually oak barrels, and then storing these vessels at a moderate temperature during a period of time according to the product needs and the regulatory requirements for this product. The capacity of oak barrels is between 200 and 600 litres.

## **2.1.5 Heat processing (E)**

### **2.1.5.1 Melting (E.1)**

#### **2.1.5.1.1 Objective**

The objective of melting is to obtain a phase change from solid to liquid, to prepare the material for further processing, e.g. for fats and processed cheese, or to recover the melted fraction, i.e. in fat recovery.

#### **2.1.5.1.2 Field of application**

The main applications of melting in the FDM sector are in chocolate moulding, the production of processed cheese, the processing of oils and fats and the recovery of animal fat from meat residues.

#### **2.1.5.1.3 Description of techniques, methods and equipment**

For melting, processing kettles are used. These can be operated either batch wise or continuously. Heating may be carried out by direct steam injection or indirectly by steam jackets. Processing kettles are available in various sizes and shapes. In continuous processing, scraped surface heat-exchangers are applied.

### **2.1.5.2 Blanching (E.2)**

#### **2.1.5.2.1 Objective**

Blanching is designed to expose the entire product to high temperatures for a short period of time. The primary function of this operation is to inactivate or retard bacterial and enzyme action, which could otherwise cause rapid degeneration of quality. Two other desirable effects of blanching include the expelling of air and gases in the product, and a reduction in the product volume.

#### **2.1.5.2.2 Field of application**

Blanching is an important step in the processing of fruit and green vegetables.

#### **2.1.5.2.3 Description of techniques, methods and equipment**

Before blanching, the food is preheated. Blanching may be accomplished by direct or indirect heating systems. This may depend on the product. Direct heating is normally made by immersion into hot water, at 80 to 100 °C, or by exposure to live steam. The operation is normally carried out in horizontal chambers. The residence time in the blancher can vary from approximately 1 to 5 minutes depending on the fruit or vegetable being blanched. For some products, direct contact with water is to be avoided so heat-exchangers working with hot water or vapour are applied. Indirect heating is described in Section 2.1.5.8. After blanching, the food is cooled using either water or air.

### **2.1.5.3 Cooking and boiling (E.3)**

#### **2.1.5.3.1 Objective**

Cooking and boiling are heat processing techniques applied to foodstuffs, principally to make the food edible. They also alter the texture, colour and moisture content of the food and may facilitate other later processes.

### 2.1.5.3.2 Field of application

Cooking and boiling are applied on an industrial scale for the preparation of ready-to-eat meals, in the preparation of complete meals and for meal components, such as in various meat products. They are also applied to heat foodstuffs prior to final processing.

### 2.1.5.3.3 Description of techniques, methods and equipment

In this document, cooking is distinguished from roasting, which is described in Section 2.1.5.5. **Cooking** is carried out in ovens. There are several different types of ovens; water bath, shower, steam, hot air and microwave.

Water bath ovens allow the best homogeneity of heating to be obtained. The immersion into hot water causes weight loss, and results in proteins and greases being released into the water. **Boiling** is cooking in a water bath oven at boiling temperature.

Shower ovens allow a good uniformity of heating. They include the simultaneous action of water sent through the showers and the saturated steam which rises from the collecting basin, at the bottom of the oven, which is heated, in turn, by coils.

In steam ovens, the water shower is eliminated and any heating is only due to the steam produced in the collection basin.

Hot air ovens include, when it is necessary to control surface humidity, a steam inlet and a recirculation of hot air which is obtained by passage through heat-exchangers.

In a microwave oven, food is heated by passing microwaves through it, the resulting generation of heat inside the food facilitates rapid cooking.

### 2.1.5.4 Baking (E.4)

#### 2.1.5.4.1 Objective

Baking is a heat processing technique, principally to make the food edible. It can also change the taste and texture. Another objective of baking is to preserve the food by destruction of the micro-organisms and reduction in the  $a_w$  at the surface of the food. However, the shelf-life of most baked foods is limited, unless products are refrigerated or packaged.

#### 2.1.5.4.2 Field of application

Baking is used to prepare ready-to-eat products such as bread, cakes and biscuits. Baking can be applied to fruit and vegetables. Baked vegetables may be used as a filling or as a topping component in many food products such as pies, pizzas and snack foods.

#### 2.1.5.4.3 Description of techniques, methods and equipment

In a baking oven, the food is exposed to hot air at 110 to 240 °C, or to infrared irradiation. The moisture at the surface is evaporated and removed by the hot air. When the rate of moisture loss at the surface exceeds the rate of transport of moisture from the interior of the product to the surface, the surface dries out and a crust is formed.

It is a common problem with filled food products that the moisture content of the filling component, commonly fresh vegetables, adversely affects the casing or base component of the food product during storage, via moisture migration into the casing or base. The alternative of conventional dehydrated vegetables is not suitable, since these have undesirable taste and texture properties and require rehydration prior to use. Baked vegetables do not have these drawbacks. Suitable vegetables for this process include courgettes, peppers, mushrooms, potatoes, cauliflowers, onions, artichokes and aubergines.

There are four types of ovens; direct heating, indirect heating, electric and infrared ovens. All oven types can be batch or continuous in operation. In batch ovens, the walls and the base are heated. In continuous ovens, radiators are located above, alongside and below the conveyor belt. Batch ovens incur higher labour costs than continuous ovens. Another disadvantage can be the non-uniformity in baking times, caused by the delay in loading and unloading the oven.

In direct heating ovens, air and combustion gases are recirculated by natural convection or by fans around the product to be baked. The temperature in the oven is controlled by adjusting the air and fuel flowrates to the burner. The fuels normally used are natural gas, propane and butane. The gas is burned in ribbon burners above or sometimes below the conveyor belt and product. The advantages of direct heating ovens are their short baking times, high thermal efficiencies, rapid start-up and good temperature control. Good management and care is necessary to prevent contamination of the food by undesirable products of combustion.

In indirect heating ovens, the air in the baking chamber is heated via a heat-exchanger, by steam or by burning a fuel. The air in the baking chamber is typically recirculated through the baking chamber and the heat-exchanger. Other methods include passing the combustion gases through radiator tubes in the baking chamber, or burning the fuel between a double wall whilst exhausting the combustion gases from the top of the oven.

Electric ovens are heated by induction, heating radiator plates or bars.

In infrared ovens for baking vegetables, the raw material is washed and sliced or diced. The vegetable pieces are then flash blanched for 60 to 80 seconds, in 100 % saturated steam in a jet stream oven at 200 to 300 °C. The steam is delivered to the oven at a rate of approximately 500 to 540 kg/h. The air speed in the oven is 17 – 25 m/s. The product is transferred next into a second jet stream where it is steam cooked at 270 to 300 °C in 50 % saturated steam for 65 to 85 seconds, without changing the steam and air speed conditions. The product is then transferred to an oven for infrared baking for 3.5 to 5 minutes. The air temperature in the oven increases from 240 to 350 °C as the product travels through the oven on a conveyor belt. In this process, the vegetables lose approximately 30 to 60 % of their water content, depending on the vegetable.

### **2.1.5.5 Roasting (E.5)**

#### **2.1.5.5.1 Objective**

The aim of the process is to cook the food to make it edible, to produce dry products and/or to enhance the structure of raw products.

#### **2.1.5.5.2 Field of application**

Typical ingredients that are roasted are coffee, nuts, cacao, chicory, fruit, cereals and pre-processed cereals.

#### **2.1.5.5.3 Description of techniques, methods and equipment**

The raw product is usually exposed to hot air at temperatures of over 100 °C. Sometimes the raw product is pre-dried. If so, first the water is evaporated from the product to decrease the moisture content of 8 to 20 % to less than 1 %. If the product reaches a sufficiently high temperature, i.e. over 120 °C, reactions take place in the product. These so-called Maillard reactions are important in the formation of aromas in coffee and cacao. The duration of this roasting process depends on the product and the specific aromas that are required. Roasting times for coffee range between 1 and 20 minutes, while for cacao and other products this can be up to 180 minutes. When the product temperature reaches the required level, the Maillard reactions are stopped by either cooling the product with air or by quenching the product with water followed by cooling with air.

Roasting can be carried out either batch wise or continuously. Typical equipment for batch roasting are a drum roaster, a column roaster, a rotating disc roaster, a fluidised bed roaster and a spouting bed roaster. Common to all equipment is that the product is heated and agitated at the same time. The product can be in direct contact with the hot air, called convective heat transfer, or in contact with a heated surface, called conductive heat transfer. Usually it is a combination of both. The cooling takes place in separate equipment. This can be a cooling sieve where air is pulled through or a spouting bed cooler or any other equipment where the raw product is in contact with fresh air. Quenching with water can take place in the roasting chamber and sometimes in the cooling equipment. Cyclones are used as an integral part of the process to remove dust, mainly consisting of product residues and skins (chaff) before it is exhausted to the air. The recovered material is then reprocessed. The cooling air is also emitted to the air.

### **2.1.5.6 Frying (E.6)**

#### **2.1.5.6.1 Objective**

The objective of frying is to cook in edible oil at temperatures in the region of 200 °C. Vegetable oil, or a mixture of animal fat and vegetable oil, is normally used.

#### **2.1.5.6.2 Field of application**

Raw materials such as fish, potatoes and chicken can be fried, e.g. in the production of products such as fish fingers, potato chips and chicken nuggets.

#### **2.1.5.6.3 Description of techniques, methods and equipment**

The product is fed into the fryer on a slatted belt. The fryer is a horizontal chamber containing the oil. The product drops into the oil and if it is coated in batter, this expands and brings the product to the surface of the oil. The slatted belt feeds the product under the main fryer belt, which takes the product through the fryer and controls the frying time. The take-out belt at the end of the fryer lifts the product out of the oil, allows drainage and transfers the product to the inspection and packing belts. Fryers are equipped with a fume extraction fan to eliminate fume leakage. The frying temperature and time vary according to the product being processed. Temperatures range from 190 to 205 °C and residence times in the fryer are normally around 35 seconds, but can be as long as 6 minutes.

### **2.1.5.7 Tempering (E.7)**

#### **2.1.5.7.1 Objective**

The objectives of tempering are to ensure product quality and appearance, enable handling of liquid chocolate for various applications, e.g. demoulding, and ensure viscosity control and enable net weight requirements to be met. Tempering is also the controlled thawing of meats.

#### **2.1.5.7.2 Field of application**

Tempering is applied in the manufacture of chocolate and products containing chocolate. Chocolate formulations containing cocoa butter, or cocoa butter equivalents, need to be tempered before use. Chocolate may be under-tempered, well-tempered or over-tempered depending on the particular application.

Tempering is done because cocoa butter can exist in various crystalline forms, which if left untempered transform into unstable forms that impact severely on production capability and product quality. The process ensures that the fat is crystallised into stable forms which then enables products to be manufactured with good gloss and hardness, and to be crispy if needed. It also delays the formation of grey white spots on the surface known as fat bloom.

### 2.1.5.7.3 Description of techniques, methods and equipment

The tempering process involves the melting of all the fat crystals present by heating to at least 40 °C or above, then cooling the mass to typically below 30 °C, known as the seeding temperature. This allows formation of stable crystalline forms, which, on holding, enables a further desirable transformation to occur. Finally the mass is warmed slightly to melt out any remaining unstable crystalline forms and to establish further crystallisation of the stable forms. Depending on the particular recipe or formulation, temperatures and holding times will vary accordingly to ensure the optimum product quality.

Single stream tempering uses the standard technique of inducing crystallisation of the stable forms from liquid followed by changes in temperature. The product is carried by a conveyor screw feed into a tempering tube where it is tempered in three stages.

Twin stream tempering requires an already seeded stream to be introduced into a molten untempered chocolate stream.

Finally, multistage tempering is based on gentle cooling to produce seed crystals, followed by gentle reheating to allow the formation of stable crystalline forms. The cooling and reheating zones are made up of multistages maintained at the required temperature ranges via a jacketed recirculating water system. Various tempering machines are available based on this principle and are widely used in industry for a wide range of applications.

### 2.1.5.8 Pasteurisation, sterilisation and UHT (E.8)

#### 2.1.5.8.1 Objective

The conservation of food and feed products is achieved by the killing of the micro-organisms present. Heat treatment for the conservation of products is one of the main techniques used in the FDM sector. Heat treatment stops bacterial and enzyme activity and so prevents loss of quality and reduces food perishability. In heat treatment processes, various time/temperature combinations can be applied, depending on the product properties and shelf-life requirements.

**Pasteurisation** is a controlled heating process used to eliminate viable forms of any micro-organism, i.e. pathogen or spoilage causing, that may be present in milk, fruit-based drinks, some meat products, and other foods, or to extend shelf-life as is the case with beer. A similar controlled heating process, referred to as blanching, is used in the processing of fruits and vegetables. Both pasteurisation and blanching are based on the use of the minimum heat requirement needed to deactivate specific micro-organisms or enzymes, thus minimising any quality changes in the foods themselves [87, Ullmann, 2001]. In pasteurisation, generally a heating temperature below 100 °C is applied.

**Sterilisation** is a controlled heating process used to eliminate viable forms and spores of any micro-organism, i.e. pathogen or spoilage causing, that may be present in a preserved food. This can be achieved by moist heat, dry heat, filtration, irradiation, or by chemical methods. Compared to pasteurisation, a heat treatment of over 100 °C is applied for a period long enough to lead to a stable product shelf-life.

**UHT** is a heat treatment of over 100 °C for a very short time.

#### 2.1.5.8.2 Field of application

**Pasteurisation** and **sterilisation** are used to treat all types of FDM products; these include milk, juices and beer. **UHT** is applicable to low viscosity liquid products.

### 2.1.5.8.3 Description of techniques, methods and equipment

**Pasteurisation** temperatures commonly range from 62 to 90 °C, and pasteurisation times vary from seconds to minutes. Batch wise pasteurisation uses a temperature of 62 to 65 °C for up to 30 minutes. High temperature short time (HTST) pasteurisation uses a temperature of 72 to 75 °C for 15 to 240 seconds. High heat short time pasteurisation (HHST) applies a temperature of 85 to 90 °C for 1 to 25 seconds.

Batch wise pasteurisation is carried out in agitated vessels. Sometimes the product, i.e. beer and fruit juices, is pasteurised after bottling or canning. Here the products in their containers are immersed in hot water or fed through a steam tunnel. For continuous pasteurisation, flow-through heat-exchangers, e.g. tubular, plate and frame, are applied. These have heating, holding and cooling sections. Table 2.2 shows examples of heat treatment combinations used in the FDM sector.

| Process   | Heating temperature/<br>holding time | Use   |
|---|--------------------------------------|---|
| Bulk liquid pasteurisation                            | 63 °C/30 min                         | Vat pasteurisation of milk                                    |
| High temperature short time pasteurisation (HTST)     | 72 °C/15 s                           | Continuous pasteurisation of milk for food safety             |
| Cooking of meat products                              | 65 to 75 °C internal temperature     | Ready-to-eat products, e.g. ham, meat loaves and frankfurters |
| Blanching of vegetables                               | Variable, e.g. 75 °C/5 min           | Enzyme deactivation and tissue softening                      |
| In-bottle pasteurisation                              | 60 °C/10 min*                        | Shelf-life extension of beer                                  |
| *the parameter may vary depending on the type of beer |                                      |   |

**Table 2.2: Examples of heat treatment combinations used in the FDM sector [1, CIAA, 2002]**

Generally for **sterilisation**, the product is canned or bottled and then heat-treated in a steriliser with steam or hot water. Sterilisers may be batch or continuous. In sterilisation with moist heat, temperatures generally range from 110 to 130 °C with sterilisation times being from 20 to 40 minutes. For example, canned foods are sterilised in an autoclave at about 121 °C for 20 min. Higher temperatures and shorter times may have similar effects, e.g. 134 °C for 3 min. However, if conditions do not allow the germination of spores, lower temperatures and shorter times can also be applied. For example, with acid fruit juices, jam, or desserts, heating up to 80 to 100 °C for 10 minutes is normally sufficient.

For killing bacterial endospores by dry heat, longer exposure times and higher temperatures are required than with moist heat, e.g. up to 2 hours at 160 to 180 °C. Solutions containing thermolabile compounds can be sterilised by filtration through mediums such as nitrocellulose membranes, diatomaceous earth, e.g. kieselguhr, and porcelain. UV irradiation is used to keep rooms partially sterile. Bacteria and their spores are killed quickly, but fungal spores are only moderately sensitive to radiation. Ionising radiation, e.g. X-ray and gamma radiation, is used to sterilise food and other compact materials. Chemical means may also be applied. Ethylene oxide is used to sterilise food, plastics, glassware, and other equipment [87, Ullmann, 2001].

**UHT treatment** means a very short heat treatment at temperatures of 135 to 150 °C for only a few seconds. This results in a sterilised product with minimal heat damage to the product properties. UHT treatment is only possible in flow-through equipment. The product is thus sterilised before it is transferred to pre-sterilised containers in a sterile atmosphere. This requires aseptic processing. For UHT treatment, indirect heating in plate and frame or tubular heat-exchangers is applied. Direct steam injection or steam infusion may also be applied.

## 2.1.6 Concentration by heat (F)

### 2.1.6.1 Evaporation (liquid to liquid) (F.1)

#### 2.1.6.1.1 Objective

Evaporation is the partial removal of water from liquid food by boiling. For instance, liquid products can be concentrated from 5 % dry solids to 72 %, or even higher, depending on the viscosity of the concentrates. Evaporation is used to pre-concentrate food, to increase the solid content of food, to change the colour of food and to reduce the water content of a liquid product almost completely, e.g. as in edible oil drying.

#### 2.1.6.1.2 Field of application

Evaporation is used in many FDM sectors. For example, it is used to process milk, starch derivatives, coffee, fruit juices, vegetable pastes and concentrates, seasonings, sauces, sugar and edible oil.

#### 2.1.6.1.3 Description of techniques, methods and equipment

Steam, vapour, or exhaust gases from other drying operations, are usually used as the heating medium. The latent heat of condensation is transferred to the liquid food to raise its temperature to boiling point, to evaporate the water. The vapour is then removed from the surface of the boiling liquid. Since food products are heat sensitive, it is often necessary to work at low temperatures. This is achieved by boiling the liquid part under vacuum. Evaporation normally occurs in the range of 50 to 100 °C, although it can be as high as 130 °C in the sugar industry.

In its simplest form, evaporation is carried out by boiling off water to the air, using immersed electric heaters. However, in practice the most commonly used equipment is multistage shell and tube evaporators, or plate evaporators. Shell and tube evaporators may be natural or forced circulation, climbing or falling film types. Centritherm evaporators, wiped film evaporators (WFE), thin film evaporators and vacuum pans are specially designed for the evaporation of highly viscous products. Typical total solids concentrations for various types of evaporators are shown in Table 2.3. The level of total solids in the outlet depends on the composition of the product to be concentrated.

| Evaporator type             | Total solids inlet (%) | Total solids outlet (%) |
|-----------------------------|------------------------|-------------------------|
| Shell and tubes, multistage | 5 – 25                 | 40 – 75                 |
| Plates, multistage          | 5 – 25                 | 40 – 75                 |
| Vacuum pans                 | 60 – 70                | 80 – 85                 |
| Centritherm, single-stage   | 5 – 25                 | 40 – 60                 |
| WFE, single-stage           | 40 – 50                | 70 – 90                 |

**Table 2.3: Typical total solids concentrations for various types of evaporators**  
[1, CIAA, 2002]

Multiple-effect evaporators are used when evaporation requires significant energy, e.g. in sugar beet processing, starch production and the evaporation of milk and whey. These evaporators use fresh steam or exhaust gases from other operations, and so recover or re-use energy, to boil off water vapour from the liquid in the first effect. The evaporated water still has sufficient energy to be the heat source for the next effect, and so on. A vacuum is applied in a multiple-effect series to allow the water to boil off. The liquid being processed is passed from one evaporator body through the others so it is subjected to multiple stages of evaporation. In this way, one unit of steam injected in the first evaporator can remove three to six units of water from the liquid.

Additional energy can be saved by recompressing the vapour using a thermal vapour recompressor (TVR) or a mechanical vapour recompressor (MVR). However, this can lead to steam contamination, making it unsuitable for return to the boilers and, therefore, increasing the waste water load. In the final stage, the vapour may be condensed by cooling with cooling water. Some of the vapours can be drawn off the evaporators to be used as heat sources for other process requirements. The condensate may be of such a quality that it may even be fed to other processes as process water.

During processing, product compounds gradually deposit on the heat-exchange surfaces. This can affect the efficiency of the heat-exchange and lead to heat losses in the system. These deposits may be inorganic or organic, depending on the product. The installation must, therefore, be cleaned at regular intervals to prevent too high a heat loss occurring with a subsequent loss of product quality.

### **2.1.6.2 Drying (liquid to solid) (F.2)**

#### **2.1.6.2.1 Objective**

Drying is defined as the application of heat under controlled conditions to remove the water present in liquid foods by evaporation to yield solid products. It differs from evaporation, which yields concentrated liquid products. The main purpose of drying is to extend the shelf-life of foods by reducing their  $a_w$ .

#### **2.1.6.2.2 Field of application**

Typical applications for drying techniques include dairy products, e.g. milk, whey and creamers, coffee, coffee surrogates, tea, flavours, powdered drinks, and processed cereal-based foods.

#### **2.1.6.2.3 Description of techniques, methods and equipment**

Two different principles can be applied for drying; hot air drying and surface drying by heat conduction through a heat transfer system.

In hot air drying, hot air is used as the heating medium and is in direct or indirect contact with the liquid product. The heat transferred from the hot air to the product causes evaporation of the water content.

In surface drying by heat conduction through a heat transfer system, the heating medium is not in contact with wet food but separated from it by a heat transfer surface. The heat is transferred by conduction through the surface, and by convection from the hot surface to the food product for evaporating and removing water from the food. This has two main advantages compared to hot air driers; less air volume is required and, therefore, thermal efficiency is higher, and the process may be carried out in the absence of oxygen.

The driers used are spray, roller, and vacuum band and vacuum shelf driers.

In spray drying, the material to be dried is suspended in air, i.e. the liquid is converted into a fog-like mist or atomised liquid, providing a large surface area. The atomised liquid is exposed to a flow of hot air in a drying chamber. The moisture evaporates quickly and the solids are recovered as a powder consisting of fine, hollow, spherical particles. Air inlet temperatures of up to about 250 °C or even higher, depending on the type of product, are used, but due to evaporation, the air temperature drops very rapidly to a temperature of about 95 °C, which is the outlet temperature of the air. The product temperature is 20 to 30 °C below the air outlet temperature. Heating the drying air can be accomplished by steam or by direct gas-fired air heaters or by indirect heaters fired by gas, liquid or solid fuels. Spray drying is applied on a large scale in the dairy industry and for drying coffee.

Generally, as an integral part of the process, the exhaust air is passed through cyclones and/or filters to recover particulate materials or dust which are carried over in the exhaust air. The recovered material is incorporated back into the product.

The principle of roller drying is that a thin film of material is applied to the smooth surface of a continuously rotating, steam-heated metal drum. The film of the dried material is continuously scraped off by a stationary knife located opposite the point of application of the liquid material. The drier consists of a single drum or a pair of drums with or without satellite rollers. The applied steam pressure in the drums can vary from 4 to 8 bar, depending on the product. Roller drying is applied, e.g. for milk, starch and potato flakes.

Finally, in vacuum band and vacuum shelf driers, food slurry is spread or sprayed onto a steel belt, which passes over two hollow drums within a vacuum chamber. The food is first dried by the steam-heated drum, and then by the steam-heated coils or radiant heaters located over the belt. The dried food is cooled by the second water-cooled drum and removed by a doctor blade. The rapid drying and limited heat damage to the food makes this method suitable for heat-sensitive foods.

### **2.1.6.3 Dehydration (solid to solid) (F.3)**

#### **2.1.6.3.1 Objective**

Dehydration is defined as the application of heat under controlled conditions to remove, by evaporation, the water present in solid foods or by-products from agricultural raw material processing. The main purpose of dehydration is to extend the shelf-life of foods by reducing their  $a_w$ .

#### **2.1.6.3.2 Field of application**

Some examples of dried foods are dried potatoes, starch derivatives, sugar beet pulp, flour, pasta, beans, fruit, nuts, cereals, meal of oilseeds, tea leaves, vegetables and spices. The dehydration of wet germinated grain is applied in the production of malt which is also called kilning. For the malting process, the drying step is essential and is required to create the desired colour and flavour.

#### **2.1.6.3.3 Description of techniques, methods and equipment**

Dehydration affects food texture and colour, and causes the loss of volatile components, all of which have a detrimental effect on both the quality and the nutritional value of the food. The design and operation of dehydration equipment aims to minimise these changes by selecting appropriate drying conditions for individual foods. For dehydration, the two different principles are, i.e. hot air drying and surface drying by heat conduction through a heat transfer system. These are explained in detail in Section 2.1.6.2.

Various types of driers are used, i.e. fluidised, cabinet or tray, conveyor or belt, pneumatic, flash and/or ring, rotary, tunnel, steam bundle, steam, kiln and vacuum driers.

FBDs are composed of metal trays with mesh or perforated bases that can contain a bed of particulate foods up to 15 cm deep. Hot air is blown through the bed, causing the food to become suspended and then vigorously agitated. The air acts as both the drying and the fluidising medium. They can be batch or continuously operated. FBDs are compact and allow a good control over the drying conditions and relatively high thermal efficiencies and high drying rates. These driers have very high rates of heat and mass transfer and consequently short drying times. Drying can take place with air temperatures below 100 °C, but may also be up to 170 °C or higher depending on the product/process. FBD is often applied as a last drying step after spray drying (see Section 2.1.6.2), in the dairy industry.

Cabinet or tray driers consist of an insulated cabinet fitted with a shallow mesh or perforated trays, each of which contains a thin layer of food. Hot air is circulated through the cabinet. A system of ducts and baffles are used to direct air over and/or through each tray to promote a uniform air distribution. These driers are used for small scale production and have low capital and maintenance costs. They are relatively difficult to control and produce variable product quality.

Continuous conveyor or belt driers are up to 20 metres long and 3 metres wide. The food is dried on a mesh belt. The airflow is initially directed upwards through the bed of food and then downwards in later stages to prevent dried food from blowing out of the bed.

In pneumatic, flash and/or ring driers, powders or particulate foods are continuously dried in vertical or horizontal metal ducts. A cyclone separator or a bag filter is used to remove the dried product. The moist food is metered into the ducting and suspended in hot air. They have relatively low capital costs, high drying rates and thermal efficiencies, and good control over the drying conditions.

Rotary driers are slightly inclined rotating metal cylinders fitted internally with flights that cause the food to cascade through a stream of hot air as it moves through the drier. Airflow may be parallel or countercurrent. The agitation of the food and the large area of food exposed to the air produces high drying rates and a uniformly dried product. The method is especially suitable for foods that tend to mat or stick together in belt or tray driers. It is used on a large scale in the sugar industry for sugar and beet pulp drying. In the case of pulp, exhaust gases from the combustion plant may be used as a heat source when the physical plant and the flue-gas temperature allows. Some combustion plants can produce flue-gas temperatures of around 120 °C.

In tunnel driers, thin layers of food are dried on trays, which are stacked on trucks programmed to move semi-continuously through an insulated tunnel in which hot air is circulated.

In steam bundle driers, the heating medium or steam is not in contact with the wet product. A heat transfer surface is used to transfer the heat to the product's surface for drying. The steam passes through the drier, through cylindrical tubes/bundles which rotate, to avoid local overheating and to improve uniform drying. This drier uses less air volume and subsequently emissions into the air are limited.

Steam drying is a special drier design that uses superheated steam produced via a heat-exchanger. The drier consists of a pressure vessel in which the water from the product is driven off, turned into steam and then used to dry more product. This system is used in the sugar industry, on a limited scale, for drying beet pulp. One advantage is the low energy consumption for drying.

Drying in kilns is used for malting and is described in Section 2.2.15.

Vacuum drying is used for temperature sensitive products. The external pressure is lowered to avoid drying at a high temperature. One simple type of vacuum drying is vacuum roller drying. In this method, either one or two rollers are installed in a vacuum housing. The resulting vapour precipitates in a condenser located between the vacuum chamber and the pump. The product is removed by a screw conveyor.

## 2.1.7 Processing by the removal of heat (G)

### 2.1.7.1 Cooling, chilling and cold stabilisation (G.1)

#### 2.1.7.1.1 Objective

Cooling is used to reduce the temperature of the food from one processing temperature to another or to a required storage temperature. Chilling is a processing technique in which the temperature of a food is reduced and kept at a temperature between -1 and 8 °C. The objective of cooling and chilling is to reduce the rate of biochemical and microbiological changes in foods, to extend the shelf-life of fresh and processed foods, or to maintain a certain temperature in a food process, e.g. in the fermentation and treatment of beer. Cooling is also used to promote a change of state of aggregation, e.g. crystallisation. The objective of cold stabilisation is to precipitate out tartrates in wines, or fatty acids in spirits before bottling.

#### 2.1.7.1.2 Field of application

Cooling, chilling and cold stabilisation are widely used in the FDM sector.

Chilling is used for preservation of a lot of perishable foods. In the wine sector, cooling and chilling are applied to clarify the must before fermentation. Cold stabilisation is used in the beer, wine and spirit sectors. Beer is cold stabilised to precipitate the protein-polyphenol adduct. The beer is kept between -2 and -3 °C for at least 12 hours.

#### 2.1.7.1.3 Description of techniques, methods and equipment

**Cooling** of liquid foods is commonly carried out by passing the product through a heat-exchanger or cooler or by cooling the vessels. The cooling medium in the cooler can be groundwater, water recirculating over a cooling tower, or water, eventually mixed with agents like glycol, which is recirculated via a mechanical refrigeration system or ice-water system.

In cryogenic cooling, the food is in direct contact with the refrigerant, which may be solid or liquid carbon dioxide, or liquid nitrogen. As the refrigerant evaporates or sublimates, it removes heat from the food, thereby causing rapid cooling. Both liquid nitrogen and carbon dioxide refrigerants are colourless, odourless and inert.

The supply of **chilled** foods to consumers requires a sophisticated distribution system, involving chilled stores, refrigerated transport and chilled retail display cabinets. Chilled foods can be grouped into three categories according to the storage temperature [225, Hendley B., 1985]. A fourth category is applied to winemaking.

- -1 to 1 °C for fresh fish, meats, sausages and ground meats, smoked meats and fish
- 0 to 5 °C for pasteurised canned meat, milk and milk products, prepared salads, baked goods, pizzas, unbaked dough and pastry
- 0 to 8 °C for fully cooked meats and fish pies, cooked or uncooked cured meats, butter, margarine, cheese and soft fruits
- 8 to 12 °C for the wine industry. The must is kept at this temperature for 6 to 24 hours.

The equipment used for freezing (see Section 2.1.7.2) can also be used for **cooling and chilling**.

**Cold stabilisation** is a technique for chilling wines before bottling to cause the precipitation of tartrate crystals. For spirits, this technique consists of bringing the spirit to a temperature of between -1 and -7 °C, depending on the operators, and possibly performing a stabulation, i.e. storing at low temperature, in tanks at constant temperatures for between 24 and 48 hours. A cold filtration, around -1 °C, allows the fatty acid esters to be retained. For wines, three techniques can be employed; cold stabilisation by batch and stabulation, continuous cold stabilisation, and cold stabilisation by crystal seeding. The two last techniques are the most widely-used. There can be many variations on these basic schemes.

Cold stabilisation by batch and stabulation is the oldest technique. It consists of bringing the wine to a temperature below zero close to freezing point and then stabulating it in an isothermal tank for a period of five to eight days.

$$\text{Freezing point (}^{\circ}\text{C)} = - (\text{alcohol (\% v/v)}/2) + 1$$

In continuous cold stabilisation, the stabulation tank is replaced by a cylindro-conical crystalliser and an agitator, in which the wine will remain for only 30 to 90 minutes.

Cold stabilisation is carried out by crystal seeding, consisting of refrigerating at between -1 and -2 °C, and seeding at 4 g/l of tartaric crystals with agitation over 2 to 4 hours, and later storage in tanks, followed by decantation after 12 to 48 hours.

### 2.1.7.2 Freezing (G.2)

#### 2.1.7.2.1 Objective

Freezing is a preservation method. In freezing, the temperature of a food is reduced to below the freezing point and a proportion of the water undergoes a change in state to form ice crystals. The sector standard for freezing food is to reduce the temperature to around -18 °C.

#### 2.1.7.2.2 Field of application

Several types of food can be frozen, e.g. fruits, vegetables, fish, meat, baked goods and prepared foods such as ice-cream and pizzas.

#### 2.1.7.2.3 Description of techniques, methods and equipment

During freezing, the heat is first removed to lower the temperature of the food to the freezing point. This includes removal of heat produced by respiration as in fresh foods. The latent heat of crystallisation is then removed and ice crystals are formed. Table 2.4 shows the typical freezing points of various FDM products.

| FDM product   | Freezing point  |
|---|-----------------|
| Meat, poultry, and fish   | -0.6 to -2.0 °C |
| Vegetables, e.g. peas, cauliflowers, onions, carrots and tomatoes | -0.9 to -1.4 °C |
| Fruits, e.g. pears, plums and apricots                            | -1.8 to -2.5 °C |
| Berry fruits, e.g. strawberries and raspberries                   | -0.8 to -1.2 °C |
| Milk  | -0.5 °C         |
| Ice-cream   | -4.0 to -6.0 °C |

**Table 2.4: Typical freezing points of various FDM products**  
[37, Environment Agency of England and Wales, 2000]

A whole range of methods and equipment for freezing foods is available. The most common freezers used are blast, belt, fluidised bed, cooled surface, immersion and cryogenic freezers. Cryo-extraction and concentration by cold are also used.

In blast freezers, cold air at -30 to -40 °C is circulated over the food at a velocity of 1.5 to 6 m/s. In batch blast freezers, the food is stacked on trays in rooms or cabinets. In continuous equipment, trays covered with food are stacked on trolleys or the food is moved through a freezing tunnel by conveyor belts. Sometimes multiphase tunnels are applied with a number of belts. The product falls from one belt onto another, this also breaks up clumps of frozen food. The thickness of the food layer on the belts can vary from 25 to 125 mm. In blast freezers, large volumes of air are recycled, however, this can cause freezer burn and oxidative changes to unpackaged food. Moisture from the food is transferred, via the air, to the refrigeration coils, which makes frequent defrosting necessary. Impingement freezing and cooling with air velocities of up to 45 m/s and down to -50 °C is also applied.

The operating principle of a countercurrent freezer, e.g. a belt freezer or a spiral freezer, is the same as that of a blast freezer, except the food being frozen is transported through a countercurrent of cold air or liquid nitrogen. This reduces the evaporation of water from the food.

In fluidised bed freezers, the food is fluidised with air of  $-25$  to  $-40$  °C by passing the air vertically upwards through a perforated tray or conveyor belt and through a bed of food 2 to 20 cm thick. The shape and size of the food pieces determine the thickness of the fluidised bed and the air velocity for fluidising. In this system, food comes into more extensive contact with the air than in blast freezers, so that all surfaces are frozen simultaneously and uniformly. This results in faster freezing and less dehydration, which also results in less frequent defrosting. Fluidised bed freezing is restricted to small particulate foods, e.g. peas, sweet maize kernels, shrimps, and strawberries.

In cooled surface freezers, vertical or horizontal hollow plates are cooled with a refrigerant of about  $-40$  °C. The food is put on the surface in thin layers. Sometimes the plates are pressed slightly together. This improves the contact between the food and the freezing plates. One advantage of such freezers is that little dehydration of the food takes place, which reduces the frequency of defrosting. A special form is the scraped surface freezer. This consists of a freezing cylinder containing rotating knives which remove the frozen material from the freezing surface. This type of equipment is used, e.g. in ice-cream production.

In immersion freezers, packaged food is passed through a bath of refrigerated glycol, brine, glycerol or calcium chloride solution on a submerged mesh conveyor. High freezing rates are obtained with this method. It is used, e.g. for freezing concentrated orange juice in cans and for pre-freezing film wrapped poultry prior to blast freezing.

In cryogenic freezing, the food is in direct contact with the refrigerant, which can be solid or liquid carbon dioxide or liquid nitrogen. The refrigerant evaporates or sublimates away removing the heat from the food and causing rapid freezing. Liquid nitrogen and carbon dioxide refrigerants are colourless, odourless and inert.

Cryo-extraction is a method of subtractive enrichment which consists of removing water from bunches of grapes to increase the sugar content of the must. The objective of cryo-extraction is to eliminate some water present in the raw material by selective freezing. The grapes are placed in a coldroom at a temperature midway between the freezing temperature of the richest grapes and that of the least rich grapes. The duration of the treatment of the grape crop is from 12 to 20 hours at temperatures of between  $-3$  and  $-6$  °C. The technique is performed only on grapes harvested manually and carried out in low, perforated crates, to achieve a slow and homogeneous lowering of the temperature over all the grapes. The pressing makes it possible to select the ripest juices, i.e. those which flow out first. The maximum pressure used for pressing is 4 bar.

Finally, concentration by cold is a technique applied only for wines. It consists of eliminating a part of the water from a wine to increase its alcohol strength. This technique is regulated. The wine is cooled below the temperature where ice crystal forms, but the alcohol does not freeze. The crystals are prevented from congealing together by constant mixing. When a sufficient quantity of water has thus solidified, the liquid is separated from the crystals by centrifuges or pressure operated extractors.

### **2.1.7.3 Freeze-drying/lyophilisation (G.3)**

#### **2.1.7.3.1 Objective**

Freeze-drying or lyophilisation, is the process of removing water from a product by sublimation and desorption. The aim of the process is to preserve sensitive material that cannot be dried by evaporation. Beware of the risk of degradation of specific components at high temperatures, which would result in a loss of taste or other quality aspects.

### **2.1.7.3.2 Field of application**

The technique is used, e.g. for drying coffee extracts, spices, soup vegetables, instant meals, fish and meat.

### **2.1.7.3.3 Description of techniques, methods and equipment**

The freeze-drying equipment consists of a drying chamber with temperature controlled shelves. This can be a batch chamber, where the trays remain fixed on the heating plates through the drying operation, or a semi-continuous type, in which the trays move through a vacuum lock into a drying tunnel. The equipment also includes a condenser, to trap water removed from the product in the drying chamber and to facilitate the drying process; a cooling system, to supply refrigerant to the shelves and the condenser, and a vacuum system, to reduce the pressure in the chamber.

If the incoming product is a liquid, e.g. coffee extract, it is frozen in two steps, at two freezing temperatures and times, and then it is ground. The solid material is then fed manually or mechanically onto the trays in a drying chamber. The temperature of the drying chamber is well below 0 °C. The exact temperature depends on the product being dried. A vacuum is applied in the chamber. The ice evaporates under these conditions. This evaporation causes a further decrease in the temperature of the product, which is compensated for by adding heat by means of heating plates to the product through the temperature controlled trays. The evaporated water is refrozen on the surface of a condenser, which has a temperature well below the sublimation temperature under the existing conditions in the chamber. From time to time the condenser is de-iced by heating the condenser surface. The water is liquified and drained. The vacuum is maintained by a vacuum pump. The outlet of the vacuum pump is emitted into the air. To prevent solids entering and damaging the vacuum pump, a filter is usually applied in front of the pump.

## **2.1.8 Post processing operations (H)**

### **2.1.8.1 Packing and filling (H.1)**

#### **2.1.8.1.1 Objective**

The objective of packing is to use any products made of any materials of any nature for the containment, protection, handling, delivery and presentation of goods. Packing may be applied to raw materials and to processed goods. Filling is the process of putting the product in the package in a proper way.

#### **2.1.8.1.2 Field of application**

The majority of food products are packaged before they enter the distribution chain. In some cases packing is an integral part of the production process, which means that the packaged product is further processed. An example of this is the canning and bottling of foods and subsequent heat conservation.

### 2.1.8.1.3 Description of techniques, methods and equipment

The European Parliament and Council Directive 94/62/EC [213, EC, 1994], states the following:

#### Article 3

*Definitions for the purposes of this Directive:*

1. “packaging” shall mean all products made of any materials of any nature to be used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer. “Non-returnable” items used for the same purposes shall also be considered to constitute packaging.

“Packaging” consists only of:

- (a) sales packaging or primary packaging, i. e. packaging conceived so as to constitute a sales unit to the final user or consumer at the point of purchase;
- (b) grouped packaging or secondary packaging, i. e. packaging conceived so as to constitute at the point of purchase a grouping of a certain number of sales units whether the latter is sold as such to the final user or consumer or whether it serves only as a means to replenish the shelves at the point of sale; it can be removed from the product without affecting its characteristics;
- (c) transport packaging or tertiary packaging, i. e. packaging conceived so as to facilitate handling and transport of a number of sales units or grouped packagings in order to prevent physical handling and transport damage. Transport packaging does not include road, rail, ship and air containers;

Most FDM products involve primary, secondary and tertiary packaging processes throughout the manufacture and distribution chain.

The packaging materials used in the FDM sector are textiles, wood, metal, glass, rigid and semi-rigid plastic, flexible plastic films, paper and board.

Textiles have poor barrier properties. Textile bags are still used to transport bulk products including grain, flour, sugar and salt. Wooden shipping containers have traditionally been used for a range of foods, such as fruits, vegetables, tea, wines, spirits and beer. Wooden containers were replaced a long time ago in some sectors, and are now increasingly being replaced everywhere by plastic drums and crates.

Hermetically sealed, metal cans have high barrier properties and can withstand high and low temperatures. The materials used for metal cans are steel (tinplate or tin-free), and aluminium, but they may also be coated with tin or lacquers to prevent interactions with the foods within the can. Metal cans are widely used for soft drinks and beer. They are also used for canning sterilised foods, e.g. fruit, vegetables, condensed milk and meat products. Metal cans are recyclable. Aluminium foil is also widely used to pack several types of food.

Glass has high barrier properties, is inert, and is suitable for heat and microwave processing. However, two disadvantages of glass are the weight and the risk of fracturing. Glass bottles and jars are widely used for milk, beer, wines and spirits, preserves, pastes and purées and also for some foods and instant drinks. Glass bottles and jars are re-usable and recyclable.

Rigid and semi-rigid plastic containers include bottles, jars, cups, trays and tubs made from single or co extruded polymers. They are low weight, tough and unbreakable, easy to seal, have reasonably high barrier properties and great chemical resistance. Several techniques are available for the production of these containers, such as thermoforming, blow moulding, injection blow moulding, extrusion blow moulding and stretch blow moulding. Typical materials used are PVC (polyvinylchloride), PS (polystyrene), PP (polypropylene), XPP (expanded polypropylene, for thermoforming), HDPE (high density polyethylene), PET (polyethylene terephthalate), and polycarbonate. The containers are often made on-site. Some of the containers are re-usable, e.g. polycarbonate bottles for milk. Rigid and semi-rigid plastic containers are typically used for milk, soft drinks, dairy products, margarine, dried foods and ice-cream.

Flexible films are formed from non-fibrous plastic polymers, which are normally less than 0.25 mm thick. Typical materials used for flexible films are PE (polyethylene), LDPE (low density polyethylene), PP, PET, HDPE, PS, and PVC. In general, flexible films are relatively cheap; they can be produced with a range of barrier properties; they are heat sealable; add little weight; can be laminated to paper, aluminium and other plastics; and are easy to handle. Flexible films are used for packaging a large range of both wet and dry food products.

Finally, paper and board can be produced in many grades and many different forms. It is recyclable and biodegradable and can easily be combined with other materials. Laminated cardboard packs are used on a large scale for milk and fruit juices. Paper and board are also extensively used for food packaging and often as secondary packaging.

An important step in the packing process is the sealing of the container or packs. The maintenance of the food quality depends largely on adequate sealing of the packs. Seals are usually the weakest part of the packs and also suffer most frequent faults during production, e.g. when food is trapped in a seal, incorrect sealing temperatures or incorrect can seamer settings. Cans are seamed and bottles and jar glass are sealed with metallic caps, plastic caps or cork. Form-fill-sealing is now a well established technique. In this process, the container is formed and partly sealed, filled and then finally closed by full sealing.

The requirements for filling are accuracy, to ensure that the required amount of product is packed and hygiene, to ensuring that the product is hygienically filled at the correct temperature to guarantee the highest possible quality and optimum shelf-life. The selection of an appropriate filling technique depends on the nature of the product and the production rate required. The filling can be by level, volume or weight.

Level filling is most frequently used in the drink industry, especially for beer. Volumetric filling is applied to liquids, pastes and powders. The most common is the piston filler. Finally, weight filling is applied to large particulate materials, e.g. confectionery. These are filled into containers using a photoelectric device, to count individual pieces. Also multi-head weighers are being developed which aim to weigh different products simultaneously, prior to filling into the same container.

Containers need to be filled accurately without spillage and without contamination of the seal. The filling of liquid foods like milk and fruit/vegetable juices can be categorised by the temperature of the food at the time of filling, e.g. hot, ambient or fresh cold filling, or as aseptic filling. The temperature ranges involved in the filling process are best illustrated by the hot filling and fresh cold filling processes. Hot filling is undertaken at temperatures of up 95 °C, to inactivate certain relevant micro-organisms, whilst many drink products are formulated with ingredients that do not need to be heat treated to be microbiologically safe and these are, therefore, fresh cold filled at between 0 and 5 °C. For aseptic packing, pre-sterilised, e.g. by hydrogen peroxide, containers are necessary, and the filling needs to take place in a sterile zone.

### **2.1.8.2 Gas flushing and storage under gas (H.2)**

#### **2.1.8.2.1 Objective**

Gas flushing is a process in which products are stored in an artificially produced atmosphere, normally within a plastic container such as a hermetically sealed tray or pouch. The process is also referred to as modified atmosphere packing (MAP), and is used to enhance the colour-retention of, e.g. fresh meat or cured meats such as bacon and cooked ham, especially in sliced form. MAP is also applied to extend shelf-life. The impact of MAP depends on the combination of product, packaging materials and gas mix.

Storage under gas is applied to wines. Inert gas is applied to wines in tanks in place of sulphur dioxide (SO<sub>2</sub>). This is carried out to preserve an adequate CO<sub>2</sub> content and the organoleptic qualities of the wine, to protect it from oxidation, and to the prevention of bacterial deviations. It also allows the prevention in the alteration of tanks which would be emptied, e.g. in the case of bulk sales to private individuals. Finally, it permits the conservation of sterile fruit juices.

### 2.1.8.2.2 Field of application

Gas flushing is mainly used for meat and meat products. It is also used for bakery products. Storage under gas is, above all, applied to white wines, rosés and red primeurs.

### 2.1.8.2.3 Description of techniques, methods and equipment

In gas flushing, the gas mixtures used will vary depending on whether the meat to be protected is fresh or cured. The desirable bright red colour of fresh meat can be prolonged by storage in an atmosphere with some oxygen, whereas the purple-red colour of uncooked cured meat and the pink colour of cooked cured meat is preserved better in an atmosphere completely free of oxygen. In all types of meat or meat products, gas mixtures are used which also contain carbon dioxide (CO<sub>2</sub>). This inhibits bacterial growth on the meat and marginally extends the shelf-life. Normal air contains 78 % nitrogen, 21 % oxygen, and less than 1 % CO<sub>2</sub>. In comparison, typical gas mixes for use with meats and meat products are shown in Table 2.5.

|             | Nitrogen | Oxygen | CO <sub>2</sub> |
|-------------|----------|--------|-----------------|
| Fresh meat  | 20 %     | 60 %   | 20 %            |
| Cured meats | 80 %     | 0 %    | 20 %            |

**Table 2.5: Typical gas mix composition for gas flushing**  
[1, CIAA, 2002]

Solid CO<sub>2</sub>, usually in pellet form, can be added to meat during size reduction. This has the effect of rapidly reducing the temperature of the mixture and creating a blanket of inert gas over the surface of the meat, thereby enhancing the colour retention. A temporary increase in the CO<sub>2</sub> content of the air surrounding the equipment will occur, but this dissipates rapidly.

Solid or liquid nitrogen or CO<sub>2</sub> is sometimes used to partially freeze meats prior to slicing. This involves passing the pieces of meat to be sliced through a tunnel in which they are sprayed with the liquefied gas to reduce their temperature to about -8 °C. In such instances, extractor fans are located near the ends of the tunnel to expel the surplus gas to the air. No adverse effects have been reported.

**Storage under gas** consists of putting a gas, which can be either food quality nitrogen or a nitrogen/CO<sub>2</sub> mixture, in a tank under very slight overpressure of 0.1 to 0.2 bar. Nitrogen is used in a compressed state in steel containers. CO<sub>2</sub> is used in a liquefied form under pressure.

## 2.1.9 Utility processes (U)

### 2.1.9.1 Cleaning and disinfection (U.1)

#### 2.1.9.1.1 Objective

Processing equipment and production installations are cleaned and disinfected periodically to comply with legal hygiene requirements. The frequency can vary considerably depending on the products and the processes. The aim of cleaning and disinfection is to remove product remnants, other contaminants and micro-organisms.

#### 2.1.9.1.2 Field of application

The whole FDM sector.

### 2.1.9.1.3 Description of techniques, methods and equipment

Before starting the cleaning process, equipment is emptied as far as possible. Cleaning and disinfection can be carried out in various ways. Traditionally, it has been carried out manually. Cleaning in place (CIP), washing in place (WIP) and, cleaning out of place are all expressions used for different ways of cleaning. Cleaning agents are delivered in a variety of ways, e.g. in bags, e.g. powdered cleaning agents, drums or bulk tankers. Many cleaning agents are potentially hazardous to the health and safety of the operator and systems can be provided to minimise the risk during the storage, handling, use and disposal.

CIP is used especially for closed process equipment and tanks, whether stationary or small mobile, processing units. The cleaning solution is pumped through the equipment and distributed by sprayers in vessels, tanks and reactors. The cleaning programme is mostly run automatically, and applies the following steps; pre-rinse with water, circulation with a cleaning solution, intermediate rinse, disinfection, and final rinse with water. In automatic CIP systems, the final rinse-water is often re-used for pre-rinsing or may be recycled/re-used in the process. In CIP, high temperatures of up to 90 °C are used, together with strong cleaning agents. CIP systems used for open systems like freezers are almost entirely automatic, except for some dry clean-up and opening of hatches. Temperatures for medium pressure systems are normally below 50 °C and the pressure is 10 to 15 bar.

Cleaning out of place is used when several of the machine's components need to be dismantled, usually before the manual or automated cleaning of the machine is started. The dismantled components are cleaned separately outside the machine. Forming machines are one example of this. There are augers, pistons, valves, forming plates and seals which all have to be dismantled before cleaning the machine. High pressure jet cleaning, using gels and foams can be carried out manually or automatically. The appropriate cleaning method is an appropriate combination of cleaning factors such as water, temperature of the cleaning solution, cleaning agents, i.e. chemicals, and mechanical forces. Only mild conditions, with regard to temperature and cleaning agents, can be used for manual cleaning.

High pressure jet cleaning and foam cleaning are generally applied for open equipment, walls and floors. Water is sprayed at the surface to be cleaned usually at a pressure of about 40 to 65 bar. Cleaning agents are injected into the water, at moderate temperatures of up to 60 °C. An important part of the cleaning action takes place due to mechanical forces.

In foam cleaning, a foaming cleaning solution is sprayed onto the surface to be cleaned. The foam adheres to the surface. It stays on the surface for about 10 to 20 minutes and is then rinsed away with water. Foaming can be carried out both manually and automatically. Gel cleaning is similar to foam cleaning.

In some cases, cleaning is undertaken using hot water only, however, this depends on the nature of the product and the process, nevertheless, cleaning agents are normally used in the FDM sector. Cleaning agents are typically alkalis, i.e. sodium and potassium hydroxide, metasilicate and sodium carbonate; acids, i.e. nitric acid, phosphoric acid, citric acid and gluconic acid; composed cleaning agents containing chelating agents, i.e. EDTA, NTA, phosphates, polyphosphates; and phosphonates, surface active agents, and/or enzymes. Disinfectants, such as hypochlorites, iodophors, hydrogen peroxide, peracetic acid and quaternary ammonium compounds (QACs), can be used.

### 2.1.9.2 Energy generation and consumption (U.2)

#### 2.1.9.2.1 Objective

FDM manufacturing requires electrical and thermal energy for virtually every step of the process. Electricity is needed for lighting, for process control of the installation, for heating, for refrigeration and as the driving power for machinery. It is usually generated and supplied by utility companies. When steam and electricity are generated on site, the efficiency factor can be considerably higher.

**2.1.9.2.2 Field of application**

Required by all processes.

**2.1.9.2.3 Description of techniques, methods and equipment**

Thermal energy is needed for heating processing lines and buildings. The heat generated by the combustion of fossil fuels is transferred to the consumers by means of heat transfer media, which, depending on the requirements, are steam, hot water, air or thermal oil.

The basic boiler/generator design generally consists of a combustion chamber, where fuel combustion takes place. The heat is initially transferred by radiation, followed by a tubular heat-exchanger for heat transfer by convection. The hot flue-gas and heat transfer media are separated from each other by a specially designed heat-exchange system. Thermal efficiencies of heat generators very much depend on the application and fuel type. Efficiencies, calculated on the basis of lowest calorific value, range from 75 to 90 %. Some products are heated up by means of direct radiation with open flames or convection with directly heated process air. In this particular case, natural gas or extra light fuel oil is burned.

In-house combined generation of heat and power (CHP) is a valuable alternative for FDM manufacturing processes for which heat and power loads are balanced. The following cogeneration concepts are used in the FDM sector; high pressure steam boilers/steam turbine, gas turbines or gas engines or diesel generators with waste heat recovery for steam or hot water generation. The overall fuel utilisation factor of CHP systems exceeds 70 % and is typically about 85 %. Energy efficiency can be up to 90 or 95 % when the exhaust gases from a waste heat recovery system, such as a steam boiler, are used for other drying purposes. The fuel conversion efficiency greatly exceeds that of any design of a commercial power station, even the latest generation of combined cycle gas turbines, which can achieve a conversion efficiency of 55 %. Sometimes surplus electricity can be sold to other users.

Natural gas and fuel oil are the most convenient fuels. However, a few installations still burn solid fuels such as coal or process wastes. The utilisation of process wastes can be a convenient and competitive source of energy, and additionally helps to reduce the cost of off-site waste disposal.

**2.1.9.3 Water use (U.3)****2.1.9.3.1 Objective**

A large part of the FDM sector cannot operate without a substantial amount of good quality water. Without sufficient good quality water it is impossible to produce high quality products. In the FDM sector, hygiene and food safety standards have to be maintained.

A systematic approach to controlling the use of water and reducing water consumption and its contamination is generally effective.

Each application of water requires its own specific quality. In the FDM sector, the quality requirements depend on whether or not contact between water and the food product is possible. Water that comes into contact with the product must, with a few exceptions, at least be of drinking water standard. Both chemical and microbiological quality aspects are important. It is advisable to conduct a regular check of the microbiological parameters of the water at the most critical places, i.e. at the point of use. This is normally incorporated in the hazard analysis critical control point system (HACCP). The quality standards for drinking water are laid down in the Council Directive 98/83/EC [66, EC, 1998].

The treatment required to produce safe water quality depends very much on the water source and its analysis. There is no general rule. A minimum treatment concept involves water filtering, disinfecting and storage, but depending on the water requirements, may also include de-ironing, desilication, or active carbon filtering. Treated drinking water is pumped from the storage tank and distributed through the installation pipework network to the users.

Additional treatment, such as softening, dealkalising, demineralising or chlorinating the water, is needed for usage in specific food processes or utilities. Ion exchangers or membrane filtration processes are the most common techniques used for this purpose.

Water pollution control can be carried out by reducing the volume and strength of waste water generated, by in-process techniques such as eliminating or decreasing the concentration of certain pollutants, e.g. dangerous and priority hazardous substances; recycling or re-using water or end-of-pipe techniques, i.e. waste water treatment, or a combination of these.

The following sources of water are used in the FDM sector: tap water, groundwater, surface water, rainwater, water originating from the raw material and process water.

Tap water is distributed by a water main. The supplier is usually responsible for the quality of the water delivered and for checking the quality of the water regularly.

The composition of groundwater is generally reasonably constant and microbiological counts are mostly low, especially in deep bore holes. In most cases, little treatment is necessary before groundwater can be used as process water or cooling water. In most countries, a licence is needed for the extraction of groundwater. The quality of the groundwater is monitored by the user. Sometimes the authorities require notification of the results of regular water quality analyses.

Surface water cannot be used for process water unless it is treated first. When available, it is often used for cooling water. A licence may be required for such use.

Depending on the region, rainwater may be a source of water. This requires a storage basin. After appropriate treatment and control, rainwater may be used for process water, in open cooling systems.

Some raw materials that are processed in the FDM sector contain a considerable percentage of water as a liquid water phase, which can be separated from the solid constituents for separate utilisation. This separation can be carried out, e.g. by pressing, centrifuging, evaporation or by using membrane techniques. Some examples are fruit juice, potato juice, sugar beet juice and milk. Such liquids can mostly be utilised if they are not used as a primary product. Sometimes they can be used without further treatment, e.g. condensate of the first stages of evaporators for boiler feed-water, but otherwise appropriate treatment is necessary.

Process waters may be used from, e.g. chiller water, pump seal water, recovered condensate, final cleaning rinses.

### **2.1.9.3.2 Field of application**

Water is used in the FDM sector for:

- food processing, where the water either comes into contact with, or is added to, the product
- equipment cleaning
- installation cleaning
- washing of raw materials
- water which does not come into contact with the product, e.g. boilers, cooling circuits, refrigeration, chillers, air conditioning and heating
- fire fighting.

In principle, the water used in the FDM sector may be used as process water, cooling water or boiler feed-water. These are described in Sections 2.1.9.3.3, 2.1.9.3.4 and 2.1.9.3.5.

### 2.1.9.3.3 Process water

In the FDM sector, process water is used for direct preparation of products or other items which come into direct contact with the products, cleaning and disinfection, regeneration of water treatment equipment and for various technical purposes. Water that comes into contact with the product must, with a few exceptions, at least be of drinking water standard. For the production of soft drinks and beer, often special quality characteristics are required that sometimes exceed those of drinking water quality. In fruit and vegetable processing, re-use of water is common practice, sometimes with some treatment, such as filtration, during the unit operations prior to blanching.

Examples of process water that is used for direct preparation of products or other items which come into direct contact with the products include:

- starting up of continuous process lines such as in pasteurisers and evaporators
- flushing-out the product from the process equipment at the end of a production run
- washing raw materials and products
- wet transport, e.g. in a flume
- dissolving ingredients and
- in the production of drinks.

Water of varying quality can be used for cleaning and disinfection purposes. The main steps involved in these processes are pre-rinsing with water, cleaning with cleaning agents, post-rinsing with water, and disinfection. Water is also needed for cleaning the outside of equipment, walls and floors. In this case, contact with the food product is rather unlikely, so drinking water quality is not required. However, often drinking water quality is used, to avoid any hazard.

Large quantities of process water for the regeneration of water treatment equipment are required for the removal of iron and/or manganese and for product softening and demineralisation. This water needs to be of good quality, to prevent bacteriological contamination of the filter material and the need for the water to be treated afterwards. Furthermore, it is preferable if water has a low iron content and low hardness, to prevent rapid fouling and scaling of equipment.

Finally, process water is also used for other technical purposes, e.g. cooling water is used for pump seals, seal water for vacuum pumps and water in closed circuits for hot water systems and heat-exchange systems. Water is also used for air conditioning humidity control in storage areas and for processing raw materials. If there is a risk that in the event of equipment failure, contact with the food product is possible, the water needs to be of drinking water quality.

### 2.1.9.3.4 Cooling water

Cooling water is the water used for the removal of heat from process streams and products. In the FDM sector, the cooling systems commonly applied are once-through cooling systems with no recirculation of cooling water, closed circulation cooling systems, open circulation cooling systems or cooling towers and cooling by direct contact with cooling water.

Cooling water is used in direct contact with food, e.g. after blanching of fruit and vegetables and to cool, e.g. cans and glass bottles after sterilisation.

In open cooling systems, i.e. cooling towers, not only does evaporation of the water occur but also a small part of the water is sprayed. Furthermore, in a cooling tower the conditions for growth of *Legionella* bacteria are favourable. This means that the spray of cooling towers, if contaminated, may be a possible source of legionnaires' disease. To prevent the occurrence of legionnaires' disease, companies which operate these systems must comply with regulations requiring them to manage, maintain and treat them properly [190, Health and Safety Executive, 2004]. Amongst other things, this means that the water must be treated and the system cleaned regularly. Air quality from cooling systems comes within the scope of the "Cooling BREF" [67, EC, 2001].

### **2.1.9.3.5 Boiler feed-water**

In the FDM sector, steam is generated using boilers with working pressures of up to about 30 bar. For power generation with steam turbines, higher steam pressures are needed. Steam is used for the sterilisation of tanks and pipelines. Another application is UHT treatment with direct steam injection. Sometimes steam injection is used for heating the product or for adjusting the water content of the raw material. In all these cases, more or less direct contact between steam and the food product is possible so drinking water quality is required.

Requirements generally depend on the working pressure and temperature of the boiler and the conductivity [68, European confederation of organisations for testing, 1984]. The higher the pressure and temperature, the higher the quality requirements are. This makes extensive water treatment necessary, e.g. removal of iron, softening and chemical conditioning. The quality of the boiler water is controlled by the quality of the boiler feed-water. The frequency of boiler water blowdown also controls the quality.

It is important that boiler feed-water does not cause scaling in the boiler or corrosion of the steam system. This means that boiler feed-water has to have a very low hardness and be de-aerated. Returned condensate can also be used as boiler feed-water supplemented by suitably treated make-up water.

### **2.1.9.4 Vacuum generation (U.4)**

#### **2.1.9.4.1 Objective**

Vacuums are used primarily to reduce the temperature at which operations take place, thereby reducing potential deterioration in the quality of the material being processed or, in the case of edible oil processing, to avoid unwanted oxidation of the product during processing at higher temperatures.

#### **2.1.9.4.2 Field of application**

A vacuum is applied to many unit operations in the FDM sector, e.g. drying, evaporation, neutralisation and filtration.

#### **2.1.9.4.3 Description of techniques, methods and equipment**

There are three basic systems for producing a vacuum, i.e. steam jet ejectors, reciprocating pumps, and rotary vacuum pumps.

A steam jet ejector, which can produce absolute pressures down to 1 or 2 mm Hg (133 or 267 Pa), consists of a steam nozzle that discharges a high velocity jet across a suction chamber connected to the equipment. The gas is entrained in the steam and carried into a venturi-shaped diffuser that converts the velocity energy of the steam into pressure energy. The steam and vaporised material from the ejector are condensed either directly in a spray of water, e.g. barometric condensers, or indirectly with surface type condensers or especially condensed under low temperature conditions, e.g. ice condensation below -20 °C.

With barometric condensers, the cooling water can be used on a once-through basis or recirculated, e.g. in a closed-circuit. In edible oil processing, for saponification of ffa, this is done over cooling towers, e.g. under high pH conditions. With indirect condensers, the condensate can be recovered. The size of the condenser depends on the cooling temperature used, and this also controls the amount of steam required. Chilling (see Section 2.1.7.1) or freezing (see Section 2.1.7.2) systems can be used to enable operation at low temperature, thereby reducing steam usage.

The reciprocating pump, which can produce absolute pressures down to 10 mm Hg (1333 Pa), is of the positive displacement type. Air is drawn into the pump chamber and then compressed by means of a piston before being discharged. Reciprocating vacuum pumps can be either single or multistage devices. The number of stages is determined by the compression ratio. The compression ratio per stage is generally limited to four.

Rotary vacuum pumps, which can produce absolute pressures as low as 0.01 mm Hg (1.33 Pa), are again of the positive displacement type, i.e. essentially constant volume with variable discharge pressure. The discharge pressure will vary with the resistance on the discharge side of the system. The widely used water-ring vacuum pump has the inlet and outlet ports located on the impeller hub. As the vaned impeller rotates, centrifugal forces drive the sealing liquid against the walls of the elliptical housing, causing the air to be successively drawn into the vane cavities and expelled with the discharge pressure.

### **2.1.9.5 Refrigeration (U.5)**

#### **2.1.9.5.1 Objective**

The objective of refrigeration is to preserve products. Refrigeration equipment is needed for cooling, chilling and freezing (see Sections 2.1.7.1 and 2.1.7.2).

#### **2.1.9.5.2 Field of application**

In many FDM manufacturing processes, cooling is an important process step. Often mechanical cooling using refrigeration equipment is applied. Furthermore, many products are stored and distributed either chilled or frozen.

#### **2.1.9.5.3 Description of techniques, methods and equipment**

The main components of a mechanical refrigeration plant are the evaporator, the compressor, the condenser and the expansion chamber. The refrigerant circulates through these four components, changing in state from liquid to gas, and back to liquid again. In the evaporator, heat is absorbed from the surroundings. This causes part of the refrigerant to vaporise. Where ammonia is used as the refrigerant, the common temperatures of evaporation are -20 to -25 °C, which correspond to a pressure of 100 to 200 kPa.

Refrigerant vapour goes from the evaporator to the compressor where the pressure is raised to about 1000 kPa, which corresponds to a temperature of about 25 °C. The pressurised vapour then goes into the condenser, where the vapour is condensed. The heat absorbed by the refrigerant in the evaporator is released in the condenser. The condenser is cooled by water or air. The resultant liquid refrigerant then goes to the expansion chamber, where the pressure and temperature are reduced to restart the refrigeration cycle.

The common refrigerants used are ammonia (NH<sub>3</sub>), halogen refrigerants, i.e. chlorofluorocarbons (CFCs) and partially halogenated CFCs (HCFCs). Ammonia has excellent heat transfer properties and is not miscible with oil, but it is toxic and flammable. Halogen refrigerants are non-toxic, non-flammable and have good heat transfer properties. The interaction of halogen refrigerants with ozone in the air has resulted in the progressive prohibition of the placing on the market and use of ozone depleting substances and of products and equipment containing those substances [202, EC, 2000]. There is currently a proposal for a Regulation of the European Parliament and of the Council on certain fluorinated greenhouse gases [246, EC, 2003].

Condensers of refrigeration equipment can be divided into three types. In air-cooled condensers, the refrigerant goes through fin elements, around which the cooling air circulates. Water-cooled condensers operate by circulating cooling water inside the tubes. This condenses the refrigerant on the external tube surface. The water-cooled condenser is cooled according to the water once-through system or with water which circulates over a cooling tower. The most common type of water-cooled condenser is the tube condenser. Finally, the evaporation condenser is a combination of an air-cooled condenser and a cooling tower. Water evaporates at the surface of the condenser.

### **2.1.9.6 Compressed air generation (U.6)**

#### **2.1.9.6.1 Objective**

Compressed air is generated to run simple air tools, e.g. for pneumatic transfer, or for more complicated tasks such as the operation of pneumatic controls.

#### **2.1.9.6.2 Field of application**

Widely used in the FDM sector, e.g. on manufacturing and packaging lines.

#### **2.1.9.6.3 Description of techniques**

Oil-free compressed air is required in the FDM sector. The air used has to be of food quality. This is achieved by passing it through several filters at the outlet of the compressor.

## **2.2 The application of unit operations in the FDM sector**

Providing a detailed description of every process applied in the FDM sector is beyond the scope of this document, which is why only the most common processing techniques applied were described in the previous section. The use of these unit operations in some of the sectors is summarised in Table 2.6.

The major processes in some FDM sectors are described in the following sections. The intention is to provide a degree of information rather than to give every detail about the processes.

|      | Meat  | Fish | Meat | Potato | Fruit and veg. | Oil | Milk | Starch | Confectionery | Sugar | Beer | Malt | Non-alcohol drink | Spirit | Wine | Pet food | Coffee | Grain | Cereals | Dry pasta |
|------|---|------|------|--------|----------------|-----|------|--------|---------------|-------|------|------|-------------------|--------|------|----------|--------|-------|---------|-----------|
| A.1  | Materials handling and storage  | yes  | yes  | yes    | yes            | yes | yes  | yes    | yes           | yes   | yes  | yes  | yes               | yes    | yes  | yes      | yes    | yes   | yes     | yes       |
| A.2  | Sorting/screening, grading, dehulling, destemming/destalking and trimming | yes  | yes  | yes    | yes            | yes |      | yes    | yes           |       | yes  | yes  |                   | yes    | yes  | yes      | yes    | yes   | yes     |           |
| A.3  | Peeling   |      |      | yes    | yes            |     |      |        |               |       |      |      |                   |        |      |          |        |       |         |           |
| A.4  | Washing   | yes  | yes  | yes    | yes            |     |      | yes    |               | yes   |      |      | yes               |        | yes  |          |        |       |         |           |
| A.5  | Thawing   | yes  | yes  |        |                |     |      |        |               |       |      |      |                   |        |      |          |        |       |         |           |
| B.1  | Cutting, slicing, chopping, mincing, pulping and pressing                 | yes  | yes  | yes    | yes            |     | yes  | yes    | yes           | yes   |      |      |                   |        | yes  | yes      |        |       |         |           |
| B.2  | Mixing/blending, homogenisation and conching                              | yes  | yes  |        | yes            | yes | yes  | yes    | yes           |       |      |      | yes               | yes    | yes  | yes      | yes    | yes   |         | yes       |
| B.3  | Grinding/milling and crushing   | yes  | yes  |        | yes            | yes |      | yes    | yes           |       | yes  |      |                   | yes    | yes  | yes      | yes    | yes   | yes     | yes       |
| B.4  | Forming/moulding and extruding  | yes  | yes  |        | yes            | yes | yes  | yes    | yes           |       |      |      | yes               |        | yes  | yes      |        |       | yes     | yes       |
| C.1  | Extraction  |      |      |        | yes            |     |      | yes    | yes           | yes   |      |      |                   |        | yes  |          | yes    |       |         |           |
| C.2  | Deionisation  |      |      |        | yes            | yes | yes  |        |               |       |      |      |                   |        |      |          |        |       |         |           |
| C.3  | Fining  |      |      |        |                |     |      |        |               |       | yes  |      |                   |        | yes  |          |        |       |         |           |
| C.4  | Centrifugation and sedimentation  |      |      |        |                | yes | yes  | yes    | yes           | yes   | yes  |      |                   |        | yes  |          | yes    |       |         |           |
| C.5  | Filtration  |      |      |        | yes            | yes | yes  | yes    | yes           | yes   | yes  |      | yes               | yes    | yes  |          | yes    |       |         |           |
| C.6  | Membrane separation   |      |      |        |                | yes | yes  | yes    | yes           | yes   | yes  |      | yes               | yes    | yes  |          | yes    |       |         |           |
| C.7  | Crystallisation   |      |      |        | yes            | yes | yes  |        |               | yes   |      |      |                   |        |      |          |        |       |         |           |
| C.8  | Removal of free fatty acids by neutralisation                             |      |      |        | yes            |     |      |        | yes           |       |      |      |                   |        |      |          |        |       |         |           |
| C.9  | Bleaching   |      |      |        |                | yes |      |        |               |       |      |      |                   |        |      |          |        |       |         |           |
| C.10 | Deodorisation by steam stripping  |      |      |        |                | yes |      |        | yes           |       |      |      |                   |        |      |          | yes    |       |         |           |
| C.11 | Decolourisation   |      |      |        |                |     |      | yes    |               |       |      |      |                   |        | yes  |          |        |       |         |           |
| C.12 | Distillation  |      |      |        |                | yes |      | yes    |               |       |      |      |                   | yes    |      |          |        |       |         |           |
| D.1  | Soaking   |      |      |        | yes            |     |      |        |               |       |      | yes  |                   | yes    |      |          |        |       |         |           |
| D.2  | Dissolving  |      |      |        |                |     | yes  | yes    | yes           |       | yes  |      | yes               |        |      |          |        |       |         |           |
| D.3  | Solubilisation/alkalising   |      |      |        |                |     |      |        | yes           |       |      |      |                   |        |      |          |        |       |         |           |
| D.4  | Fermentation  |      |      |        | yes            |     | yes  | yes    |               |       | yes  |      |                   | yes    | yes  |          |        |       |         |           |
| D.5  | Coagulation   |      |      |        |                |     | yes  | yes    | yes           |       |      |      | yes               |        |      |          |        |       |         |           |
| D.6  | Germination   |      |      |        |                |     |      |        |               |       |      | yes  |                   |        |      |          |        |       |         |           |
| D.7  | Brining/curing and pickling   | yes  | yes  |        | yes            |     | yes  |        |               |       |      |      |                   |        |      |          |        |       |         |           |
| D.8  | Smoking   | yes  | yes  |        |                |     | yes  |        |               |       |      |      |                   |        |      |          |        |       |         |           |
| D.9  | Hardening   |      |      |        |                | yes |      |        | yes           |       |      |      |                   |        |      |          |        |       |         |           |
| D.10 | Sulphitation  |      |      |        |                |     |      | yes    |               | yes   |      |      |                   |        | yes  |          |        |       |         |           |
| D.11 | Carbonatation   |      |      |        |                |     |      |        |               | yes   | yes  |      | yes               |        | yes  |          |        |       |         |           |

|      |   |     |     |  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|------|---|-----|-----|--|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| D.12 | Carbonation   |     |     |  |     |     |     |     |     |     |     |     | yes |     | yes |     |     |     |     |
| D.13 | Coating/spraying/enrobing/<br>agglomeration/encapsulation | yes | yes |  | yes |     | yes | yes | yes |     |     |     |     |     |     | yes | yes |     | yes |
| D.14 | Ageing  |     |     |  |     |     |     |     |     |     |     |     |     | yes | yes |     |     |     |     |
| E.1  | Melting   |     |     |  |     | yes | yes |     | yes |     |     |     |     | yes |     |     |     |     |     |
| E.2  | Blanching   |     |     |  | yes | yes |     |     |     |     |     |     |     |     |     |     |     |     |     |
| E.3  | Cooking and boiling                                       | yes | yes |  | yes | yes |     |     | yes |     | yes |     |     | yes |     | yes |     |     |     |
| E.4  | Baking  |     |     |  |     | yes |     |     | yes |     |     |     |     |     |     | yes |     |     | yes |
| E.5  | Roasting  |     |     |  |     |     |     |     | yes |     |     |     |     |     |     | yes | yes |     | yes |
| E.6  | Frying  | yes | yes |  | yes | yes |     |     | yes |     |     |     |     |     |     | yes |     |     |     |
| E.7  | Tempering   |     |     |  |     |     |     |     | yes |     |     |     |     |     |     | yes |     |     |     |
| E.8  | Pasteurisation, sterilisation and<br>UHT                  | yes | yes |  | yes |     | yes | yes | yes |     | yes |     | yes |     | yes | yes |     |     |     |
| F.1  | Evaporation (liquid to liquid)                            | yes | yes |  | yes | yes | yes | yes | yes | yes |     |     |     |     | yes |     | yes |     |     |
| F.2  | Drying (liquid to solid)                                  |     |     |  | yes | yes | yes | yes | yes |     |     |     |     |     | yes | yes |     |     |     |
| F.3  | Dehydration (solid to solid)                              |     | yes |  | yes | yes |     | yes | yes | yes | yes |     |     |     | yes | yes |     |     |     |
| G.1  | Cooling, chilling and cold<br>stabilisation               | yes | yes |  | yes |
| G.2  | Freezing  | yes | yes |  | yes | yes |     |     | yes |     |     |     |     |     | yes | yes | yes |     |     |
| G.3  | Freeze-drying/lyophilisation                              |     |     |  |     |     |     |     |     |     |     |     |     |     | yes | yes | yes |     |     |
| H.1  | Packing and filling                                       | yes | yes |  | yes |
| H.2  | Gas flushing and storage under<br>gas                     | yes | yes |  |     |     | yes |     |     |     | yes | yes |     |     | yes |     | yes |     |     |
| U.1  | Cleaning and disinfection                                 | yes | yes |  | yes |
| U.2  | Energy generation and<br>consumption                      | yes | yes |  | yes |
| U.3  | Water use   | yes | yes |  | yes | yes | yes | yes | yes |     | yes | yes | yes |     | yes | yes | yes |     | yes |
| U.4  | Vacuum generation   | yes | yes |  | yes | yes | yes | yes | yes | yes |     |     | yes |     | yes | yes |     |     | yes |
| U.5  | Refrigeration   | yes | yes |  | yes | yes | yes | yes | yes |     |     | yes | yes |     | yes | yes | yes |     |     |
| U.6  | Compressed air generation                                 | yes | yes |  | yes |     |     |

**Table 2.6: Unit operations applied in different sectors**  
[1, CIAA, 2002, 87, Ullmann, 2001, 91, Italian contribution, 2001]

### 2.2.1 Meat and poultry

Beef, pork and poultry are the main types of meat processed in Europe. The activities of the meat sector can be divided into three areas, slaughtering (covered by the “Slaughterhouses and animal by-products BREF” [181, EC, 2003]), meat cutting and further processing.

Cutting is a size reduction of large to medium sized parts of food material. For cutting, knives, blades, cleavers and circular or straight saws are used. These are all electrically operated. Carcasses are cut into retail cuts of joints by the removal of bone, skin and fat. After cutting the meat, the fresh meat may be stored and dispensed under refrigeration. It can be sold in portions, or it may be combined with other products. Special derinding machines are used for separating rind and fat from pork carcasses.

The further processing of meat into, e.g. ham, bacon and sausage, is primarily carried out for preservation purposes but it is also important for taste. In the meat sector, raw meats, either whole muscles or altered meat particles, are restructured to the predetermined product characteristics.

For coarse-ground products, the meat particles are substantially reduced and then restructured back into a different physical form. The goal of muscle product processing is to keep an original intact tissue appearance in the finished product. Products, such as ham, roast beef, and turkey breast, are produced from whole muscles or sectioned muscles. An emulsifying process forms a matrix in which the fat particle is encapsulated with the protein membrane.

Grinding reduces particle size, and mixing assures uniformity of chemical composition as well as protein extraction. Chopping also reduces particle size and produces salt-soluble protein. Major processing equipment includes injectors and massagers for muscle products, grinders and mixers for coarse-ground products, and choppers and emulsifiers for emulsified products. Injecting and massaging processes facilitate brine distribution and protein extraction.

Preservation involving heat, e.g. cooking or frying, and dehydration produces foods that can be packaged and kept for an extended time at appropriate storage conditions. Preservation techniques such as fermentation, smoking, and brining/curing/pickling are used to diversify the market selection. All these processes offer a limited extension of the shelf-life by altering the environmental conditions which supports microbial growth.

The injection under pressure of a solution containing brining/curing/pickling ingredients is a widely used technique for extending the life of meat. The ingredients used are common salt, i.e. NaCl, often with sodium or potassium nitrite and other materials to impart special characteristics. This process is required for whole products such as ham, shoulder, bresaola and turkey. Traditional injection in-vein has ceased and today the technique uses multi-needle injectors, which allow a higher productivity and a major spread of pickle. The injector injects a predetermined dose of pickle containing different additives and ingredients, such as salts, polyphosphates, ascorbate, caseinate, nitrate, nitrite, glutamate and spices inside the ham or shoulder mass.

After the injections, a process which allows complete homogenisation of the ingredients and of the additives into the product takes place. This process also allows the extraction of a proteinous/saline fluid from the meat with binding effect. It involves massaging the meat inside a container turning around a vertical or inclined axis in a continuous or intermittent way, under vacuum and/or at a refrigerated temperature. Brining/curing by dry salt is required for the production of cured uncooked ham, bacon, and coppa. The latter two products can be also made in the massaging machine.

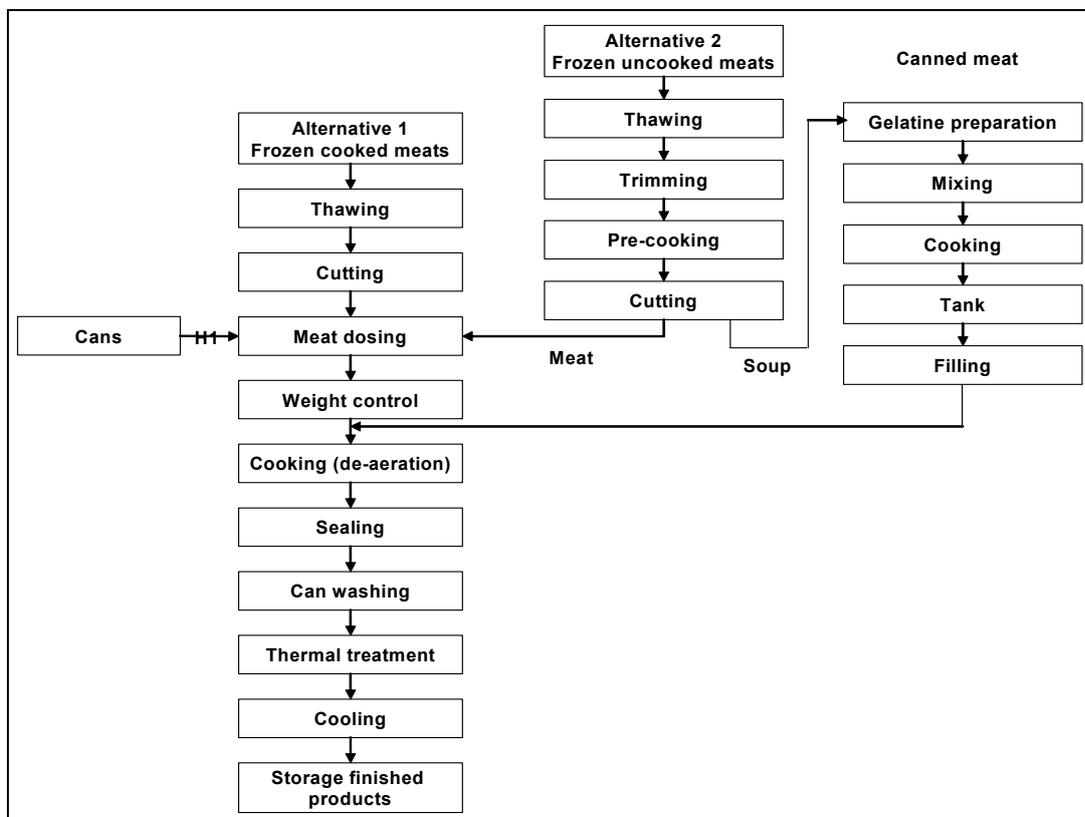
Raw meats, after these preparation processes, are stuffed into casings to form a defined geometric shape and size. During these processes, rheological properties are critical to the equipment performance and final product quality.

To recover fat from meat residues, wet melting or dry melting is used. In the wet melting process, the raw material is heated in a process kettle by direct steam injection to a temperature of about 90 °C. This results in a watery phase and a fat containing phase. The phases are separated by decantation and centrifugation. In the dry melting process, the raw material is indirectly heated in the processing kettle (a kettle with a steam jacket). All the water which evaporates is removed from the kettle under vacuum. The liquid phase or molten fat and the dry phase or fat-free meat residue are separated by decantation.

The meat sector is very diverse in terms of its products due to specific local tastes and traditions. However, three processes commonly used are canned meat, cooked ham, and cured ham production.

**2.2.1.1 Canned meat (beef muscle in gelatine)**

Different raw materials, such as cooked or uncooked, chilled or frozen meat may be used to produce canned meat. A general flow sheet is presented in Figure 2.3.



**Figure 2.3: Canned meat production**  
 [91, Italian contribution, 2001]

**2.2.1.1.1 Thawing (A.5)**

Frozen meat is generally transported in plastic bags inside a cardboard secondary packaging. Meat is stored at a temperature below -18 °C. Thawing can be achieved with air at a controlled temperature, or by an intermittent shower, or by immersion into running water. The two first methods allow a reduction in water consumption, but require longer times and larger surface areas. Moreover, the meat surface may be dried and its unsaturated fats, e.g. in pork, may be oxidised. When thawing in a water bath, the unpacked meat is put in iron crates and completely immersed in water at 15 to 18 °C. The water consumption is about 3 – 5 m<sup>3</sup>/t.

**2.2.1.1.2 Cutting (B.1)**

Fresh meat is trimmed to remove excess fat and may be deboned. About 12 % of by-products are produced in this step.

**2.2.1.1.3 Mixing/blending (B.2)**

Gelatine is prepared from industrial powder. It may come from the broth obtained during meat cooking if uncooked raw meat is used in the installation. Cooking one part of meat with one part of water gives 0.7 parts of cooked meat and 1.3 parts of broth. The broth is then filtered, boiled until the insoluble proteins precipitate, centrifuged, and filtered again. Finally, about one part of gelatine is produced. Ingredients, such as thickeners and flavours are added to the gelatine solution.

**2.2.1.1.4 Packing and filling (H.1)**

The gelatine is de-aerated and dosed in cans by a vacuum filler already containing the required part of meat. The cans are then sealed and washed with hot water to remove meat or gelatine residuals.

**2.2.1.1.5 Sterilisation (E.8)**

Cans are put in metal baskets and then sterilised in autoclaves, either in batch or continuous retorts, before being cooled.

**2.2.1.1.6 Secondary packaging (H.1)**

The cooled and dried cans are sent to be secondary packaged using cardboard boxes or bundles with a cardboard base and having a thermo-retractable wrap.

**2.2.1.1.7 Refrigeration (U.5)**

The product has a long shelf-life and does not need special care, apart from a good aeration to avoid condensation on the cans which may damage their external surfaces.

**2.2.1.2 Cooked ham**

The preservation of meat by cooking is used for several products, such as sausages, dressed pork and mortadella. The general process is shown in Figure 2.4.

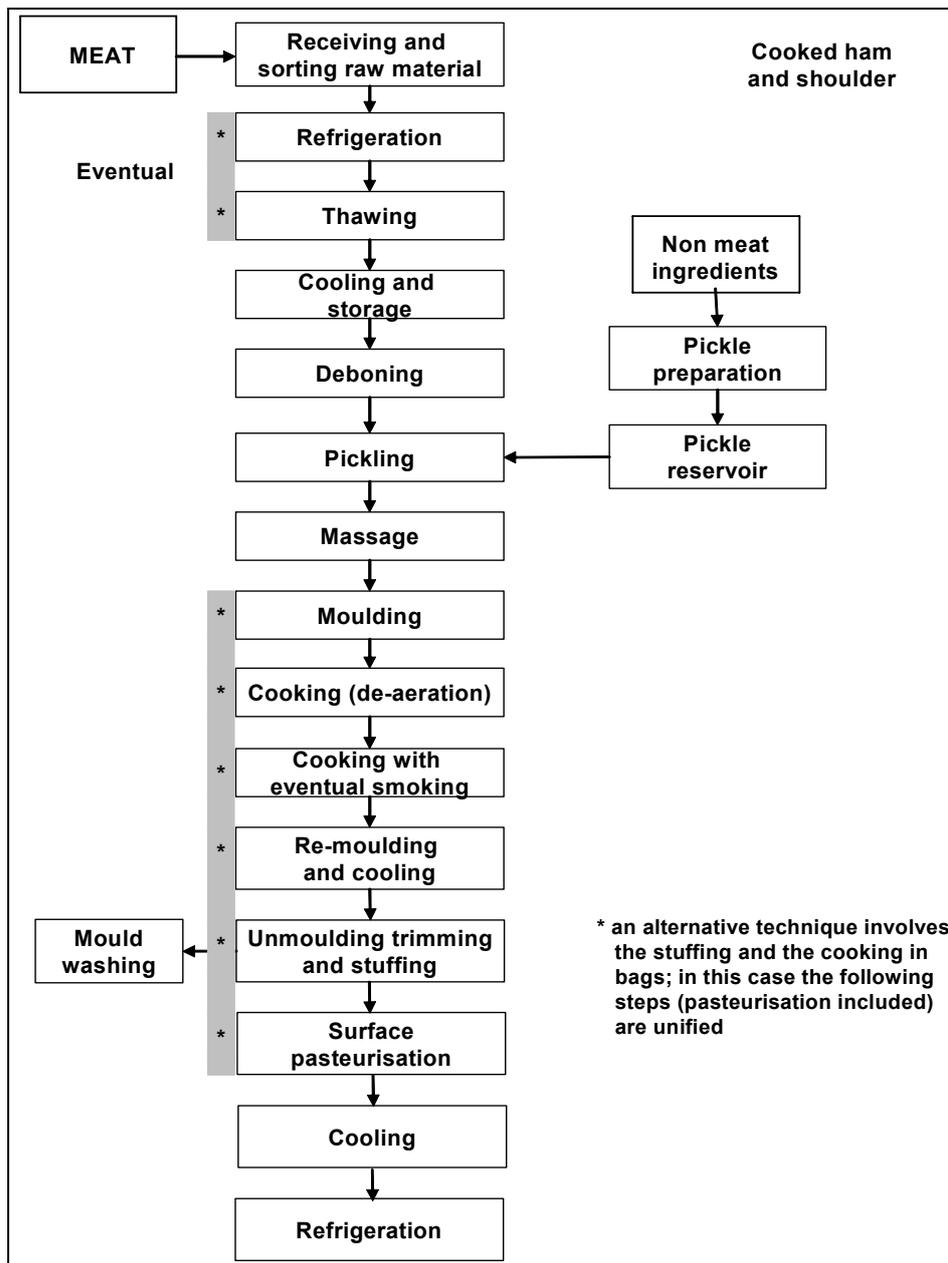


Figure 2.4: Cooked ham and shoulder production [91, Italian contribution, 2001]

First the material is received and then sorted.

**2.2.1.2.1 Thawing (A.5)**

This is similar to the canned meat process. In the production of whole hams or shoulders, the meat is held in a coldroom for 18 to 24 hours, to achieve a uniform temperature inside the meat. Losses can occur due to the dripping of meat juice.

**2.2.1.2.2 Cutting (B1)**

Ham and shoulders are manually (in an open or closed way) or mechanically (via a closed way) deboned, and degreased.

### **2.2.1.2.3 Pickling (D.7)**

Pickle injection was traditionally made “in-vein”, however, nowadays it is achieved with multi-needle injectors leading to a higher productivity and a more uniformed distribution. The injector injects a predetermined dose of pickle containing different additives and ingredients, e.g. salts, polyphosphates, ascorbate, caseinate, nitrate, nitrite and glutamate, inside the ham or shoulder mass.

### **2.2.1.2.4 Homogenisation (B.2)**

Massaging or churning allows the complete homogenisation of the ingredients and of the additives into the product, and it also allows the extraction of a proteinous/saline exudate with a binding effect. This process involves massaging the meat inside a container, which turns round a vertical or inclined axis in a continuous or intermittent way, under vacuum and/or low temperature.

### **2.2.1.2.5 Cooking (E.3)**

After moulding, the product is de-aerated and cooked and/or smoked. The cooking can be carried out in a water bath, shower, steam or hot air ovens. Water bath ovens are used for whole meat products. However, a lot of water and energy is needed, major weight loss and water pollution occurs due to the leaching of meat, but the heat transfer is homogenous. Shower ovens provide good heating uniformity and use less water and energy. Steam ovens provide a moist humid heat, where food is cooked in a gentle environment to retain its flavour and moisture. Air ovens require humidity control.

Ham may also be re-moulded and then cooled. Moulds are removed and cleaned. Ham and shoulders are normally trimmed and may be sprinkled with flour to improve the look. Packing is normally carried out under vacuum.

### **2.2.1.3 Cured ham**

Cured ham products, such as Parma from Italy, or Serrano from Spain have a good reputation because of their high quality. They are normally made of special and standard quality raw meat, e.g. typically Italian cured hams are made from 10 to 12 months old pig haunches of 150 to 180 kg weight. A similar process is used for other products, such as salami, dry sausages, and brawn. The general process is shown in Figure 2.5.

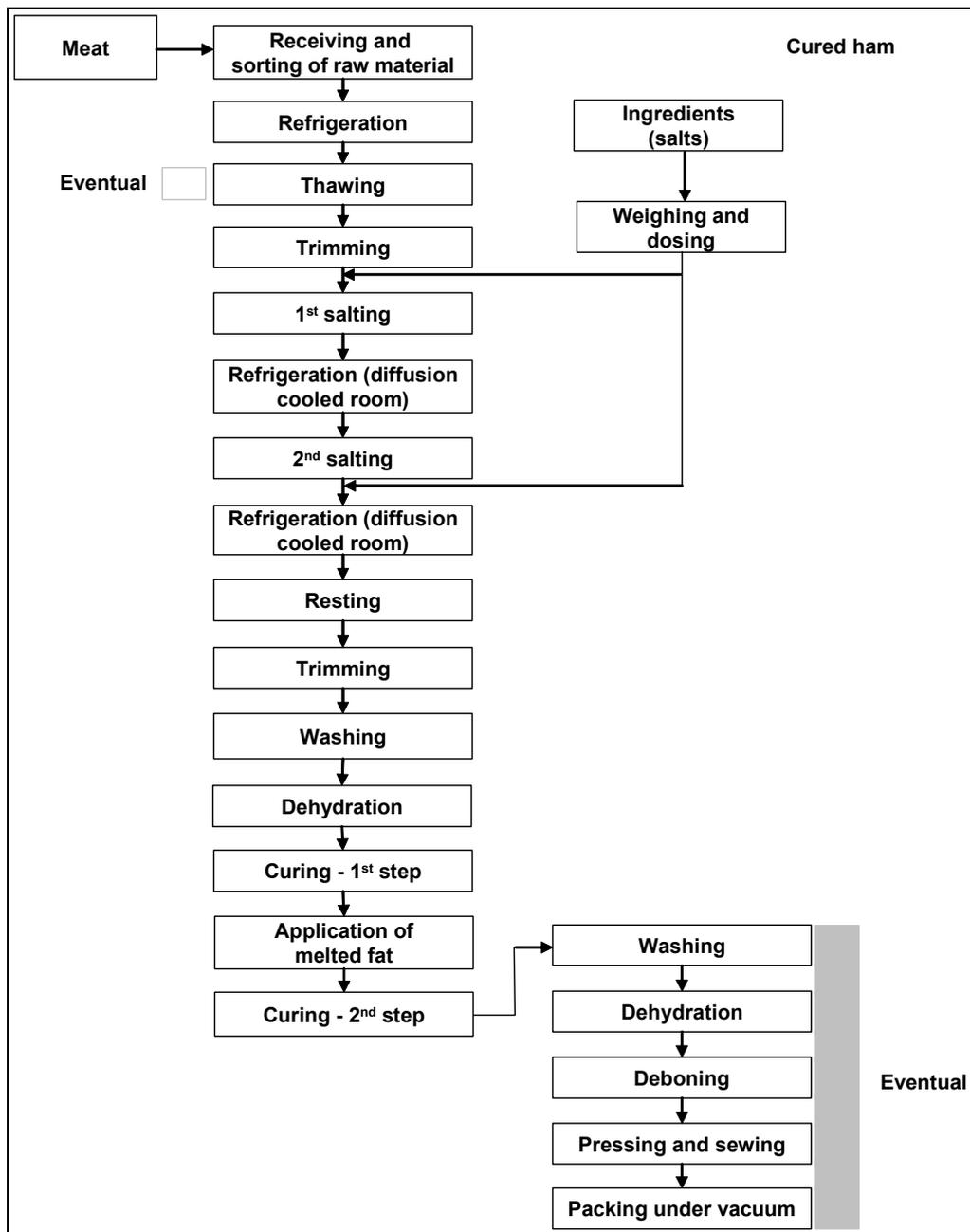


Figure 2.5: Cured ham production  
[91, Italian contribution, 2001]

Sorting, thawing, cutting and trimming, are all similar to the above described processes. Depending on the cuts, a partial peeling may be needed, e.g. for hams and bacon, as well as vein squeezing.

#### 2.2.1.3.1 Brining/curing (D7)

Curing with dry salt is specific to the production of ham and bacon and can be carried out in the churn. The main component of the curing salt is normally NaCl. Its concentration in end-products has decreased from about 6 % to less than 2 %. Nitrites may be used as a preservative against *Clostridium botulinum* and other spoilage bacteria but they also impart palatability and appearance characteristics, namely a specific taste, texture, and pink colour. Only a small amount of residual nitrite, usually <10 ppm, remains in modern cured meats.

**2.2.1.3.2 Ageing (D.14)**

Ham spends long periods of time curing under strictly controlled conditions, e.g. temperature and air humidity. In the past, ageing could take one or more years, but today, with improved technology and modern processing installations along with old family secrets, a fully cured country ham can be produced within 6 to 12 months.

**2.2.1.3.3 Washing (A.4)**

Salt and meat residuals are removed by brushing and washing. This step produces a significant amount of waste containing fats, proteins and salt. Before washing, it is better to trim the area round the thighbone head and to cut the hip.

**2.2.1.3.4 Coating (D.13)**

Before drying, hams are checked and then coated and transported to the drying chambers. Coating comprises covering the muscular part of the pig legs with pork fat or a mixture of fat and salt, pepper and flour, which has been previously sterilised. The ham then remains in these large rooms for several months, up to one year. The humidity and temperature in the room are controlled.

**2.2.1.3.5 Packing (H.1)**

With some products, the bones are removed before packaging. Other usually more traditional products are sold with the whole pig leg.

**2.2.1.3.6 Gas flushing (H.2)**

As well as traditional methods, gas flushing is also often used for packing hams.

**2.2.2 Fish and shellfish**

This sector includes the process of white or pelagic fish; fatty fish; shellfish, i.e. crustaceans and molluscs, and fresh water fish. Fish processing is very widespread and varied. Many species of fish are mass processed, including cod, tuna, herring, mackerel, pollock, hake, haddock, salmon, anchovy and pilchards. Marine fish account for 90 % of the fish production in the world. The other 10 % includes fresh water fish and farmed fish. Approximately 75 % of the world's fish production is for human consumption, with the remaining 25 % used for producing fish-meal and fish-oil. Currently, about 30 % of all the fish produced for human consumption are marketed fresh.

Fish processing most commonly takes place at on-shore processing facilities. However, some processing such as the gutting, cleaning and sometimes head removal of fish can take place at sea, on board fishing vessels, e.g. when processing white fish that has a low oil content. These fish are then kept in ice or are frozen until they arrive at the installation, where they are thawed or re-iced and stored until the time of further processing. Fatty fish have oils distributed throughout the fillet and in the belly cavity. They have different oil contents depending on the species, but on average fatty fish fillets may have up to a 30 % oil content. Typically, they are not gutted on board, as this is carried out later in the processing installations.

The pretreatment of white fish involves the removal of any ice and a screening based on their size. Large fish may also be scaled depending on the process, although this is not carried out when skinning is performed.

Skinning and cutting involves removing the edible parts of the fish and cutting it into pieces of the appropriate size. Skinning can be done manually or automatically. With automatic operations, white fish are skinned by pulling the fillet over an automatic knife, whereas fatty fish are skinned by pulling the fillet over a freezing drum. Then, fish are transported, e.g. by fluming, to cutting tables from the holding vessels and then eviscerated, i.e. head, tails and inedible parts are removed. In small fish, such as sardines, only heads and tails are removed, and for medium sized and large fish the guts are removed as well. For white fish, this stage just involves the removal of the fillet flesh, whereas for oily fish the process involves gutting, de-heading and removal of fillets.

Fish and shellfish are processed and preserved by a large variety of methods and may be consumed in their primary form, raw or cooked. They may also be further processed to produce fish or shellfish-based foods, such as moulded products or prepared dishes. Some preservation methods involved in fish and shellfish processing include freezing, chilling, canning, curing, drying, smoking, fermenting and MAP.

### **2.2.2.1 Frozen processed fish/moulded fish products and fish fingers**

During processing, frozen fish blocks, made from either layered fillets, jumbled or minced fish, are cut into the required dimensions. With moulded products, the fish off-cuts, seasoning and binding materials are fed into a moulding machine and formed into the required shape. The product then passes through a series of enrobing machines, which cover the fish with batter and/or breadcrumbs, with the type and number of enrobers being dependent upon the desired product. After enrobing, the product is fried in an edible oil. Temperatures vary but around 190 °C is typical. The fryers may be heated by thermal oil, gas or by electrical means. The fried product then travels into a freezing unit where it is subjected to a stream of cold air to reduce the product to a predetermined target temperature, -18 °C is typical.

### **2.2.2.2 Canned fish/shellfish products**

Raw fish are washed, cut into fillets and then steamed in cooking/cooling tunnels. After head removal, white fish are filleted in machines with two sets of rotating knives that cut the fillets from the bone and cut off the collar bones. The knives are watered to cool them and to clean off fish meat and scale.

Next, the two fillets are conveyed skin-side down to the skinning phase. Fatty fish are orientated in a forward direction and held into position, using water jets, until aligned with a stop plate. They are de-headed and the tails and guts are taken out before entering the filleting machine. The two fillets then proceed to the skinning stage. Filleting and skinning may be carried out manually. Descaling is sometimes achieved using caustic baths. Fish off-cuts are normally transported to the waste collection area via chutes, water flumes or conveyor belts.

After steaming, the fish are filled into cans, which contain either brine, oil or sauce. The cans are sealed by passage through a can seamer. Precooking, skinning and cutting are carried out if medium size or large fish are processed. Small fish are put in cans whole and are cooked directly in the can.

After seaming, the cans pass into a retort for sterilisation. Here, the product is heated at a sufficient temperature to inactivate any food poisoning micro-organisms. The product is then cooled with chlorinated water. Shellfish are processed in a similar manner but are often transported under a rocking motion through a scalding system to open the shells and dislodge the flesh. Additional washing and trimming steps may also be incorporated to remove sand and mud.

The curing and smoking of fish and during processing of shellfish, may also be carried out.

### **2.2.2.3 Crustaceans**

Once headed and washed, shrimps and prawns are preserved by icing or brine freezing before being transported to the processing installation. Chemicals, e.g. sodium bisulphite, are used to prevent black spots. After cooking, they are peeled and cooled with large amounts of water. Crabs are transported alive. Crab meat is picked, either manually or mechanically.

### **2.2.2.4 Molluscs**

The types of molluscs processed and consumed in Europe mainly comprise cephalopods (cuttlefish, squid, octopus) and bivalves (oyster, mussel, clam and scallop). Processing includes freezing, canning and pickling. After cooking and shell removal, washing is often carried out by blowing air at the bottom of washing tank to agitate the meat, while the grit and shell particles settle down. Some molluscs, such as oysters or mussels are pickled with vinegar and spices. Here, the meat is dipped in 3 % salt brine, drained and covered for three days with a 3 % vinegar solution containing 3 % salt. They are then drained, packed and covered with spiced vinegar.

## **2.2.3 Fruit and vegetables**

The characteristic features of fruit and vegetables are that they are soft edible plant products which, because of their relatively high moisture content, are perishable in their fresh state. A summary of the possible processing routes of some fruit and vegetables is shown in Table 2.7.

|                          | Raw material   | Processing  | Preservation method   |
|--------------------------|--|---|---|
| <b>Garden vegetables</b> | Peas, beans, spinach, potatoes, asparagus, maize and lentils                     | Put in packaging, in water                        | Thermal treatment   |
|                          | Olives, cabbage, artichokes, mushrooms, onions, peppers, carrots and cucumbers   | Put in oil, pickling/brining, sulphited           | Natural or artificial thermal treatment   |
|                          | Cabbage and cucumbers  | Lactic acid fermentation                          | Microbial treatment   |
|                          | Various garden vegetables  | Juice   | Thermal treatment   |
|                          | Various garden vegetables  | Dried   | Drying  |
|                          | Various garden vegetables  | Freezing, deep-frozen and ready to use vegetables | Cooling   |
| <b>Tomato</b>            | Tomato   | Paste   | Dehydration and heat treatment  |
|                          |  | Whole peeled                                      | Thermal treatment   |
|                          |  | Non-whole, peeled (diced or crushed)              | Thermal treatment   |
|                          |  | Juice, strained, passata                          | Thermal treatment   |
|                          |  | Powder and flakes                                 | Drying  |
| <b>Fruit</b>             | Berries, pears, apples, peaches, apricots, plums, pineapple, cherries and grapes | Put in water, in syrup                            | Thermal treatment, with optional synergetic action of sugar (reduction of $a_w$ ) |
|                          | Peaches, apricots, plums, cherries, berries and figs                             | Jam and jellies                                   | Thermal treatment, with optional synergetic action of sugar (reduction of $a_w$ ) |
|                          | Citrus   | Marmalade   | Thermal treatment, with optional synergetic action of sugar (reduction of $a_w$ ) |
|                          | Pears, apples, peaches, apricots, plums, tropical fruits and undergrowth fruits  | Juices and nectars                                | Thermal treatment   |
|                          | Various fruits   | Candies   | Action of sugar (reduction of $a_w$ )   |
|                          | Various fruits   | Concentrates                                      | Thermal treatment (reduction of $a_w$ )   |
|                          | Various fruits   | Put in alcohol                                    | Reduction of $a_w$  |
|                          | Various fruits   | Dried fruits                                      | Drying  |
|                          | Various fruits   | Frozen and deep-frozen fruit                      | Freezing  |

**Table 2.7: Summary of the possible processing routes of some fruit and vegetables [91, Italian contribution, 2001]**

### 2.2.3.1 Ready meals that predominantly contain fruit and vegetables

Some fruit and vegetables are preserved. For this purpose, depending on the type of fruit and vegetables, different processes are used, and a variety of products are made, e.g. ready meals. In most installations, a variety of fruit and vegetable types are processed simultaneously and consecutively into different products. The majority of installations process products in bulk and are subject to seasonal variations, in line with crop rotation. However, some have product lines are not affected by seasonal fluctuations. Further processing of frozen raw materials takes place throughout the year. Processing capacities are increasingly being expanded for such product processing.

### 2.2.3.2 Fruit juice

Fruit juices are produced throughout temperate and tropical areas of the world. Orange juice predominates in temperate climates and pineapple juice in tropical climates. The bulk of the world fruit juice production is from citrus fruits, mostly oranges, pomes; from apple and pear type fruits and from vine fruits. Some stone fruit juices are manufactured but in much smaller quantities.

In a typical citrus juice process, the fruit is sorted, graded and washed to remove extraneous matter such as sticks and leaves, adhering dirt and insects. The fruit is then passed through oil extraction equipment where it is subjected to hundreds of small cuts of the skin to rupture the oil sacs and release the citrus oil, which is removed by washing. Oil extraction may be carried out after juice extraction. The fruit juice is mechanically extracted and screened to remove excess pulp, pieces of skin and seeds. The screened juice is preserved by a number of methods such as canning, aseptic processing, chemical inhibition, freezing, and membrane separation. It may be concentrated before packaging to reduce transport costs. The juice may be clarified before or after preservation.

A typical pome juice process includes similar processes but without an oil extraction step. The fresh fruits are delivered to the processing installation and unloaded, washed, sorted and then crushed after eventual coring or pitting, e.g. for peaches and apricots. The white fruits are heated to avoid enzymatic browning. The crushed fruits are then strained and refined to extract the juice. For apple juice, the juice is sometimes clarified with an enzymatic treatment and filtration.

Orange, apple and tomato juices are often concentrated, normally by evaporation or in some cases by RO or cryoconcentration. The juice is obtained either from fresh fruits or from reconstituted concentrates from citrus, pineapple and other tropical fruits. It can be packed directly, as it is the case with juices, or mixed with sugar and water, as it is the case with nectars. The juices are then de-aerated and hot filled into bottles or cans.

Because of the low pH, filling with a HTST pasteurisation treatment is sufficient to stabilise the product when followed by bottle sterilisation in a steam tunnel. Aseptic packaging is carried out by pasteurising, cooling and filling, all in aseptic conditions. The filling is carried out in cardboard bricks or preformed bricks.

### 2.2.3.3 Heat treated fruit

In typical canned fruit processes, the fruit is ideally used as soon as possible after delivery, although it often has to be stored for a time under chilled conditions, e.g. apple. The fruit is first washed, then sorted and possibly trimmed, then graded or cored before peeling. A variety of methods are used for peeling, including abrasive, caustic, steam or mechanical peeling. Peeled fruit may be blanched or transferred to tanks containing materials such as brine or ascorbic acid solutions to prevent browning. If necessary, the fruit may be sliced. Products such as orange segments are subjected to acid and caustic soaks to remove stringy fibres before canning. The fruit is filled into containers, e.g. cans or glass jars, in syrup or a natural juice. Before sealing, they can be gently heated to remove entrained gases, a process known as exhausting. Filling under vacuum conditions avoids the need for exhausting. The container is then sealed, heat processed and cooled. For fruit, a pasteurising treatment with a temperature under 100 °C is sufficient.

### 2.2.3.4 Frozen fruit

The freezing of fruits is a major preservation method in its own right and it is widely used to preserve fruits which are to be further processed, e.g. for the manufacture of jam. Fruits intended for freezing are generally washed and inspected before being individually quick frozen (IQF), or packed in syrup or pureed before freezing. Typical fast freezing methods involve direct contact with a cooled solid, e.g. band or drum freezers, direct contact with cooled air or other gaseous mixtures, e.g. blast air, fluidised bed and spiral freezers, direct immersion in a cooled liquid, e.g. brine freezers, or cryogenic freezers. The process for deep-frozen fruit and vegetables is shown in Figure 2.6.

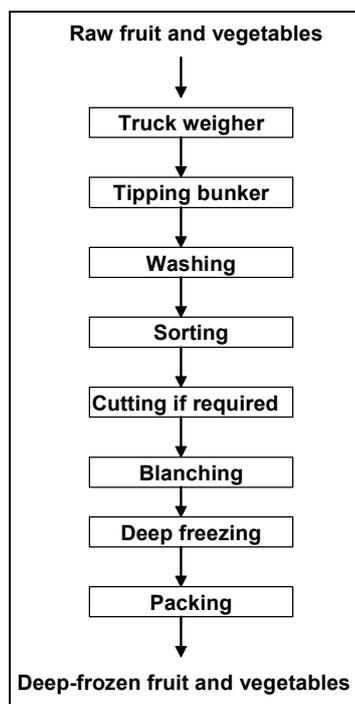


Figure 2.6: The process for deep frozen fruit

### 2.2.3.5 Fruit preserves

Preserving is the manufacture of jams, jellies, marmalades and mincemeat. It is essentially the combining of fruits and sugar with subsequent cooking. It produces a tasty product of a sufficiently high sugar content, low  $a_w$  value, and with a satisfactory shelf-life retention quality. A pasteurising treatment is applied at 85 °C or above. The jams are made using pulp and fruit juice, e.g. citrus for marmalade, and clarified juice for jellies. The basic ingredients of a preserve are fruit, sweetening agents, typically sucrose and/or various sugar syrups; acids, typically citric or malic acid; buffers such as trisodium citrate; fats, in curds/mincemeat; citrus peel, for mincemeat and marmalade; gelling agents, usually pectin and anti-foaming agents – when using frozen or sulphited fruits. In a typical process, the fruit usually arrives pre-prepared either frozen or sulphited. The prepared fruit, pectin, sucrose, glucose syrup and other small ingredients are then blended together in a mixing vessel. The mix is boiled either at atmospheric pressure or under vacuum, using batch or continuous methods. After boiling, the jam is filled into containers which vary from individual portions to bulk tank for bakery use.

### 2.2.3.6 Dried fruit

Dried fruit processing uses raw materials such as grapes, apricots, pears, bananas and plums. A basic process consists of sorting, grading, washing, drying and packing. Many fruits are sun-dried at source although some producers use mechanical methods, typically tunnels through which hot air is passed. Some fruits are sulphited before drying to preserve the fruit and soften the fruit tissue, leading to a faster loss of moisture during drying. In some cases, the fruit is sprayed or dipped after harvesting with a potassium carbonate solution which also contains dipping oil. The composition of the dipping oil varies between producers. For example, some producers use olive oil, others may use mixtures of ethyl esters of fatty acids and free oleic acid.

### 2.2.3.7 Tomatoes

In the EU, about eight million tonnes of tomatoes were processed in 2000, of which five million tonnes were processed in Italy. Significant quantities are also processed in Spain, Portugal, Greece and France. The tomatoes are made into different forms for different kinds of products. The main product is 28 to 30 °brix tomato paste obtained from the juice by concentration. Other products are whole, diced or crushed peeled tomatoes, tomato juices such as passata, and dried products such as powder and flakes. The basic processes for tomato manufacturing are shown in Figure 2.7.

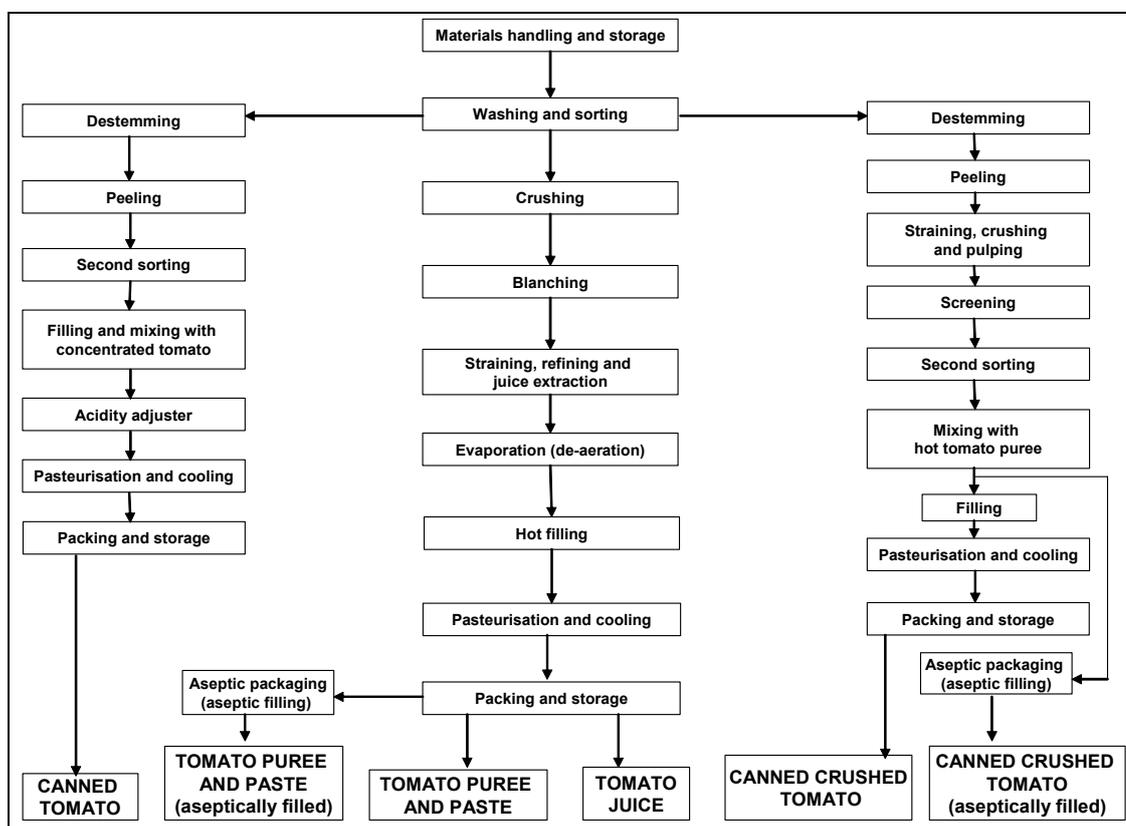


Figure 2.7: Manufacture of various tomato products [91, Italian contribution, 2001]

### 2.2.3.8 Potatoes

Two of the main potato-based products are crisps and chips. The manufacturing of both essentially consists of peeling the raw material, slicing to an appropriate size and blanching, followed by frying to achieve the desired sensory properties. To prevent colourisation of chips, a substance called pyrophosphate is used in the Netherlands. This is a very significant P-source in the waste water from potato processing installations. Sodium metabisulphate may also be used to prevent potatoes from discolouring. Chips are generally sold frozen and may be part fried or fully fried. Crisps are increasingly sold in modified atmosphere packs.

Whether the product is potato chips, mashed potatoes or another potato product, there may be foam formation in the wash bath, which can lead to serious processing difficulties. Starch foam is very stable and difficult to remove. Mechanical methods of foam control have such limited effectiveness, that the addition of foam-control agents may be the most practical solution [87, Ullmann, 2001].

### **2.2.3.8.1 Potato chips**

Potatoes are delivered to the installation and are sorted to remove stones, pebbles and other extraneous matter. The raw material is washed, graded and peeled. A number of peeling methods are available, including mechanical, steam and caustic peeling. Large tubers are generally sorted for use in chip production. Potatoes are cut into the required size using independently driven multiple knives. Off-cuts, slivers and broken pieces are removed before blanching. The chips are blanched using steam or water generally at around 60 to 85 °C. Multiple blanching stages may be used.

Excess moisture must be removed from the chips both to preserve the life of the frying oil and to lower the moisture content of the chips. This also leads to a reduction in the required frying time. Conveyor driers are used in large processing installations. The chips are fried, typically at around 160 – 180 °C, the time of frying varies for completely fried and partially fried products. Excess fat is removed from the chips before freezing. Some manufacturers recover the fat for re-use. Fluidised bed freezing may be used for freezing the finished product, although belt freezing reportedly provides a more energy efficient option.

### **2.2.3.8.2 Potato crisps**

Processing methods for the manufacture of crisps vary greatly, but generally take the form of washing, peeling, trimming and sorting, slicing, rinsing, partial drying, frying, salting, flavouring, cooling and packing. Potatoes are first washed with drum or flotation washers. Stones, sand, dirt and any extraneous matter are removed. Potatoes are elevated into washers and peeled by abrasion. Peeled potatoes are trimmed to remove eyes, bruises and decaying portions. Slicing is carried out using a series of blades mounted on a circular stationary plate and a rotating drum. Water is supplied to flush starch from the equipment. Sliced potatoes are washed, usually in drum washers, to remove surface starch and sugars.

Some manufacturers blanch crisps prior to frying using steam-jacketed water filled tanks. Typical blanching conditions are 65 to 95 °C, for one minute or more. After washing, surface moisture is removed by various methods including compressed air and blower fans, vibrating mesh belts and heated air. Crisp frying may be batch or continuous. Temperatures are in the range of 160 to 190 °C and cooking times are typically between 1.5 and 3 minutes. When the crisps leave the fryer, they are agitated to remove excess oil and discharged to a belt running underneath a salter. Flavouring may be mixed with the salt or dusted/sprayed onto the crisps in rotating drums. Finally the crisps are cooled and packed.

### **2.2.3.9 Vegetable juice**

Significant quantities of juice are produced from vegetable sources such as carrot, celery, beetroot and cabbage. In general, fresh vegetables are first washed and sorted before being coarsely milled and then pressed to extract the juice. Most vegetable juices have low acidity, i.e. a pH >4.5, and therefore, they require a full sterilisation process for preservation. Vegetable juices are sometimes acidified with organic or mineral acids to reduce the pH, so that a milder heat treatment such as pasteurisation is then possible. Some low acidity juices are blended with high acid juices such as tomato, rhubarb, citrus, pineapple or cabbage, so that they are acidic enough to only require pasteurisation. Some vegetables may be blanched prior to acidifying and extraction. Root vegetables are usually peeled before maceration and extraction.

### 2.2.3.10 Heat treated and frozen vegetables

Process conditions vary depending upon the vegetable type, but preliminary operations for both heat treated and frozen vegetables are similar to those described in Section 2.2.3.3 for fruits. They usually involve washing, grading and screening to remove extraneous matter such as stones and dirt. After washing, the vegetables are peeled and may be trimmed. After peeling the vegetables may be left whole or cut in a number of ways such as sliced or diced. Some vegetables are washed after slicing to remove the surface starch. Most vegetables require blanching. Steam or water blanching are the most common methods. The product is then cooled rapidly. After cooling, the product may be re-inspected and screened before being quick frozen or filled into cans or glass jars, usually with a hot brine, e.g. sugar, salt or acid, and then heat processed. Vegetables generally undergo a full sterilisation process as the pH is too high to inhibit microbial action.

### 2.2.3.11 Pickling of vegetables

In a typical pickling process, raw vegetables are delivered, washed and then screened to remove extraneous matter such as stones. Depending upon the vegetable, the raw material might be steam cooked and then cooled. The product is then peeled, typically using steam, and re-inspected before being cut to the required dimensions, e.g. sliced/diced/shredded, and transported to the filling line. The chopped vegetables are then filled into containers. An acidifying liquor is mixed with spices and transferred to the filling line to be used in the pickling sauce. This liquor typically consists of acetic acid, malt vinegar, spirit vinegar, distilled malt vinegar, liquid sugar and salt, depending upon the formulation. The acidifying liquor is deposited into the container. The container is sealed and typically pasteurised before cooling and packaging.

### 2.2.3.12 Vegetable drying

Vegetable drying uses raw materials such as potatoes, tomatoes, mushrooms and onions. The basic process is the same as in fruit processing, i.e. sorting, grading, washing, drying and packing. Many vegetables can be sun dried at source. Mechanical methods can also be used.

## 2.2.4 Vegetable oils and fats

Oils and fats occur naturally in a wide range of sources, although only around 22 vegetable oils are processed on a commercial scale around the world. These are summarised as:

- production of oils from oilseeds, i.e. sunflower seed, soya bean, rapeseed, safflower seed, mustard seed, cotton seed and ground nuts
- production of oils from fruit pulp, e.g. olives
- production of animal fats
- production of fish-oils.

Oils produced in the largest quantities come from soya beans, ground nuts, olives, sunflower seeds, safflower seeds, cotton seeds, mustard seeds and rapeseeds; the latter is also known as colza oil. Mediterranean countries produce 95 % of the total world olive oil production estimated to be 2.4 million tonnes per year. Animal fats for human consumption are generally produced by a process known as fat melting and by fish-oil production. Animal fat and fish-oil production is within the scope of the “Slaughterhouses and animal by-products BREF” [181, EC, 2003].

The preparation of raw materials includes husking, cleaning, crushing, and conditioning. The extraction processes are generally mechanical, e.g. boiling for fruits and pressing for seeds and nuts, or involve the use of solvents such as hexane. After boiling, the liquid oil is skimmed. After pressing, the oil is filtered. After solvent extraction, the crude oil is separated and the solvent is evaporated and recovered. Residues are conditioned, e.g. dried, and are reprocessed to yield by-products such as animal feed. Crude oil refining includes degumming, neutralisation, bleaching, deodorisation, and further refining. Oils can be processed further to produce margarine.

### 2.2.4.1 Seed oil extraction

The production of crude vegetable oil from oilseeds is a two-step process. The first process step involves the cleaning, preparation, i.e. drying, dehulling, flaking, conditioning and pressing of the oilseeds. Pressing takes place in one or two steps resulting in a crude pressed oil and a cake with an oil content of 12 to 25 %. No subsequent hexane extraction takes place, if the oil content of the cake after pressing is only reduced to between 6 and 12 %. Beans with 20 % or less are not pressed, because of their lower fat content, but are extracted directly after cleaning and preparation.

The second process step includes extraction of the oil from the pressed cake or flaked beans with hexane. The extraction takes place in a countercurrent flow. The mixture of hexane and oil, called miscella, is further processed in a distillation process to recover the hexane from the vegetable oil. The solvent is passed through a hexane/water separation technique and then re-used in the extraction process. The remaining hexane in the cake is recovered by a stripping process, using steam. This desolventising/toasting process also reduces the enzyme and micro-organism activity in the meal. The hexane/steam vapours are used in the miscella distillation process for solvent and heat recovery. The meal is dried and cooled by air before being stored in silos or before loading.

There are a variety of manufacturing methods associated with the large range of oil sources which release oil and improve subsequent extraction. A number of key steps are typically always undertaken. Coarse extraneous matter such as wood, stones and metal are first removed with, e.g. sieves or magnets. Fine impurities such as plant residues, dust and sand are then removed, e.g. by vibrating sieves, wind sifters and cyclones. The husks and hulls of seeds, such as soya and sunflowers, are removed, and the seeds are then cracked, followed by air classification, to expose the flesh of the raw material. After this, the flesh is conditioned or dried to a required moisture level, typically 9 to 10 % and rolled into flakes.

### 2.2.4.2 Refining of edible oils and fats

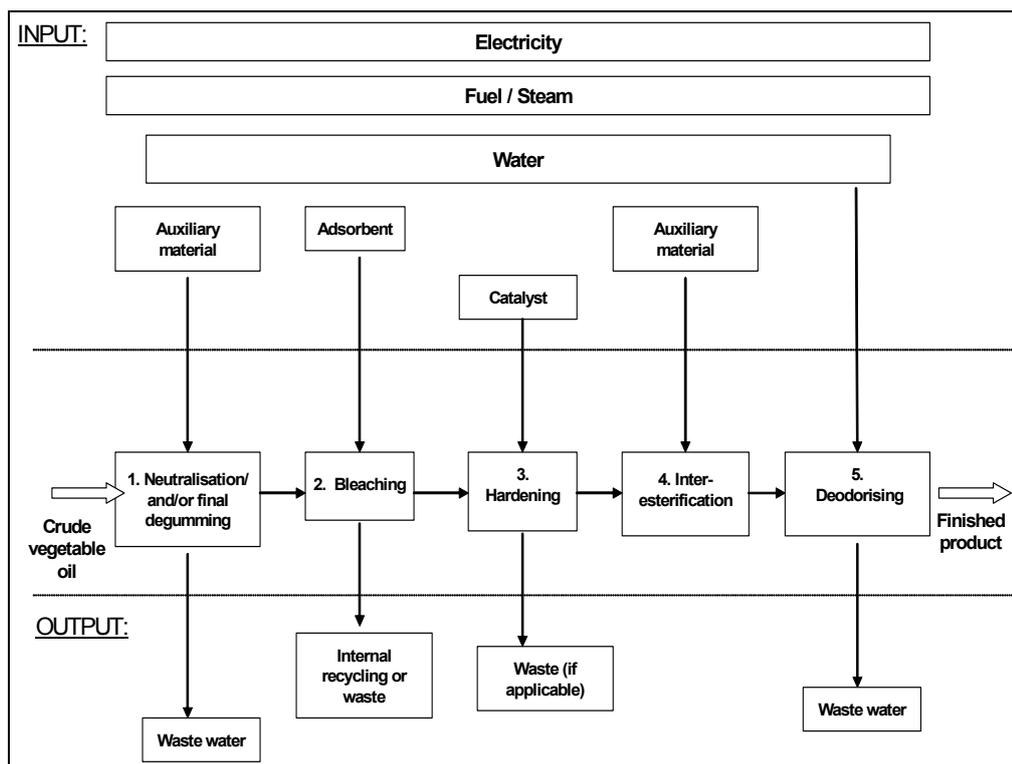
Refining removes undesirable compounds such as gums, ffa, pigments, undesirable flavours and odour compounds. In general, there are two ways to refine seed oils, i.e. physical refining and the more conventional chemical refining. Conventional chemical refining, as applied to crude oils for instance, includes degumming for the removal of phospholipids, neutralisation for the removal of ffa and bleaching for decolourisation and deodorisation.

Degumming involves the addition of water to hydrate any gums present, followed by centrifugal separation. Non-hydratable gums are removed by converting them first to a hydratable form using phosphoric or citric acid, followed by the addition of water and centrifugation.

The next step is neutralisation in which an aqueous alkali, typically caustic soda or sodium carbonate, is splashed into the oil which has been preheated to around 75 to 95 °C. The alkali reacts with the ffa in the oil to form soaps, which are separated by sedimentation or centrifugation. A drying step may be incorporated after neutralisation to ensure the complete removal of the added water.

The neutralised oil is bleached to remove colouring matter, such as carotenoids and other minor constituents, such as oxidative degradation products or traces of transition metals. Bleaching uses activated Fuller's earth with treatments typically in the 90 to 130 °C range for 10 to 60 minutes. The earth is sucked into the oil under vacuum and is removed by filtration.

The bleached oil is steam distilled at low pressure to remove volatile impurities including undesirable odours and flavours. This process, known as deodorisation, takes place in the temperature range of 180 to 270 °C and may last from 15 minutes to 5 hours depending upon the nature and the quantity of the oil, and the type of equipment used. For example, if a batch deodoriser is used, it would take between 4.5 to 5 hours depending on the oil type and the quantity. However, if the same oils were processed in a semi-continuous deodoriser it would take about 15 minutes. Figure 2.8 shows a flow diagram of crude oil chemical refining. Olive oil and husk from pomace oil refining is similar to oilseed oil refining.



**Figure 2.8: Crude oil chemical refining**  
[79, Italian contribution, 2001]

Physical refining is a simpler process in which the crude oil is degummed and bleached, followed by steam stripping which removes ffa, odours and volatiles in one step. The oil is heated to temperatures of up to 270 °C and then refined by the oil flowing over a series of trays countercurrent to the flow of the stripping steam. The advantages of physical refining are the higher yield, the lower cost and the fewer chemicals used. One of the disadvantages, compared to chemical neutralisation, can be a lower quality of the end-product.

There are three other processes which may be carried out during oil refining, depending upon the oil source. These are winterisation, which essentially is the removal of wax which would otherwise cause cloudiness. This is carried out on, e.g. sunflower oil. The process involves cooling the oil followed by filtration, using a filter aid to remove wax. The second process is fractionation. Typically this may be carried out on crude or refined oil. This involves completely melting the solid oil, followed by cooling to yield solid and liquid fractions which have different functional properties (see Section 2.2.5.3.). The third process is interesterification. This involves the separation of triglycerides into fatty acids and glycerol followed by recombination. The reaction is carried out using citric or phosphoric acid plus a catalyst, typically sodium methoxide. Interesterification modifies the functional properties of the treated oil and may be carried out after neutralisation or deodorisation.

### 2.2.4.3 Crystallisation of edible oils and fats

Crystallisation of edible oils and fats, also called fractionation, is based on the principle that the solubility of the higher melting components in the liquid phase change at different temperatures. This difference can be extended by using an organic solvent which has the effect of decreasing the viscosity and leading to better washing of the crystals.

The equipment includes tanks for preheating; stirred and cooled tanks for crystallisation; band or membrane filters for the separation of the crystals from the liquor and distillation vessels for solvent recovery. The oil is heated to 10 °C above the melting point of the highest triacylglycerol present, to give a fully liquid starting material, e.g. the heating point is typically 75 °C for palm oil. The molten oil is then cooled and stirred to form crystal nuclei, and the temperature is maintained at a lower temperature to induce crystal growth, typically for 12 hours at 28 – 30 °C for palm oil. If a solvent is used, it is added to the molten oil prior to cooling. The mixtures containing the crystallised solids and the dissolved liquids are separated by filters. If a solvent is used, it is removed from the fractions by distillation.

### 2.2.4.4 Further processing of edible oils and fats – margarine

The main products manufactured from edible oils and fats are margarine, edible fats, edible oils and mayonnaise. In view of its major outstanding importance, only margarine production is described here.

Most installations carry out hydrogenation to produce fats with superior retention qualities and higher melting points. Hydrogenation is usually carried out by dispersing hydrogen gas in the oil, in the presence of a finely divided nickel catalyst supported on diatomaceous earth. The resultant hydrogenated fats are filtered to remove the hydrogenation catalyst, subjected to a light earth bleach and deodorised before they can be used for edible purposes. After hardening, the oil is mixed with an aqueous solution to produce an emulsion. The emulsified mixture is then pasteurised, cooled and crystallised to obtain the final product.

### 2.2.4.5 Olive oil

The words “olive oil” mean the product obtained from *Olea europea*. It is composed of about 98 % glycerides with the remaining 2 % being various components naturally present in olives, some of which play a fundamental role in the olfactory and taste characteristics and which are also important for the stability and quality of the product. Olive oils and husk oils are classified on the basis of denominations and definitions from Regulation 136/66/EEC of 22 September 1966 on the establishment of a common organisation of the market in oils and fats [215, EC, 1996].

Extra virgin oils, virgin oils and ordinary virgin oils are edible; yet only extra virgin oils and virgin oils can be commercialised as they are for direct consumption. Ordinary virgin oils are commonly used mixed with refined olive oils and refined husk oils. Acid oils with an acidity higher than 3.3 degrees must be refined.

The quality of the olive oil depends on the ripeness of the olives, the type of harvesting, e.g. picking or shaking, the type of intermediate storage, and the type of processing carried out. Olives contain 38 to 58 % oil and up to 60 % water. Ripe olives should be processed as quickly as possible since lipases in the pulp cause rapid hydrolysis of the oil, impairing its quality for edible purposes. Top-grade oils are made from fresh, handpicked olives by size reduction, pasting, and cold pressing. In the production of olive oil, there are three systems currently in use for the extraction of the oil; traditional, by pressing; three-phase separation or two-phase separation.

In traditional production of olive oil, olives are ground into a paste with stone mills, however these days modern milling equipment is also used. Milling is followed by mashing, possibly with the addition of salt. The pulp is then pressed and the press oil is clarified by sedimentation or centrifugation. Traditional open-cage presses are now being replaced by continuous screw expellers. The mashed pulp can also be separated in a horizontal decanter, in which case the crude oil is re-centrifuged after the addition of wash-water. Alternatively, machines can be used to remove the kernels from the pulp and the residue is then separated using self-discharging centrifuges. Cold pressing, which yields virgin grades, is generally followed by a warm pressing at approximately 40 °C. Cold-pressed olive oil is a valuable edible oil.

In Spain, most installations use the two-phase type centrifuges, while in most other Mediterranean countries larger installations use the three-phase technique, and smaller installations typically still use traditional pressing. While the two-phases generate a paste-like waste, both the traditional and the three-phase systems produce a liquid phase, i.e. olive mill waste water, or alpechin and a press cake known as pomace, husk, or orujo. This latter product may be further treated as husk or pomace oil. The remaining solid husk is dried to 3 – 6 % of humidity and used as fuel. Olive kernel oil is obtained by pressing and solvent extraction of cleaned kernels. It is similar to olive oil but lacks its typical flavour.

Trade specifications are based primarily on the content of ffa and flavour assessment. In some countries, warm-pressed olive oil with a high acidity is refined by neutralisation, bleaching, and deodorisation, and flavoured by blending with cold-pressed oil. The press cake contains 8 to 15 % of a relatively dark oil, called sanza or orujo, which can be extracted with hexane and is used for technical purposes. After refining, it is also fit for edible consumption.

#### **2.2.4.6 Olive-pomace oil**

Olive-pomace installations process the olive-pomace remaining after the extraction of oil from the olives. Oil is extracted with solvents resulting in crude pomace oil and exhausted husks. Oil is sent to refineries and later used in the food industry, while exhausted pomace is mainly used as fuel. Refined olive-pomace oils are mixed with virgin oils different from the lampante oils. It is also classified on the basis of denominations and definitions from Regulation 136/66/EEC [215, EC, 1996].

### **2.2.5 Dairy products**

Milk is approximately 87 % water, with the remainder being protein, fat, lactose, calcium, phosphorus, iron and vitamins. Cows milk is primarily consumed, but goats and sheep milk are also consumed in significant quantities. A number of dairy products such as cream, cheese and butter are produced from milk.

#### **2.2.5.1 Milk and cream**

Raw chilled milk is received at the dairy and transferred to bulk storage. The milk may be centrifugally separated to produce skimmed or semi-skimmed milk and a cream stream. The milk is then heat treated by a variety of methods such as pasteurisation or sterilisation, also known as UHT. Heat processing may be a batch or continuous operation depending upon the quantity of the milk to be processed and the method employed.

The milk is first homogenised. Homogenisation disperses fat globules and prevents separation of the cream component. To achieve a sufficient creaming stability for pasteurised milks with a relatively short shelf-life, reduction of the fat globules size to a mean diameter of 1 to 2  $\mu$  is required, while the long shelf-life UHT milks require a much greater reduction in fat globule size,  $\leq 0.7 \mu$ .

Another effect of homogenisation is the large increase in exposed fat area, which greatly favours the action of lipases. For this reason, it is normal practice to pasteurise the milk to inactivate the lipase, immediately after homogenisation. Figure 2.9 shows a flow sheet for a short time pasteurised milk process.

Typical heating parameters for a continuous pasteurisation process are 72 °C for 15 seconds. This is known as high temperature short time pasteurisation (HTST). Hot milk is often used to partially heat incoming cold milk in a heating step known as regeneration. Following pasteurisation, the milk is rapidly cooled to <7 °C. Milk which is not in-container heat processed, is filled and sealed in containers under clean or aseptic conditions. Incoming milk may be homogenised after the regeneration stage, before being pasteurised.

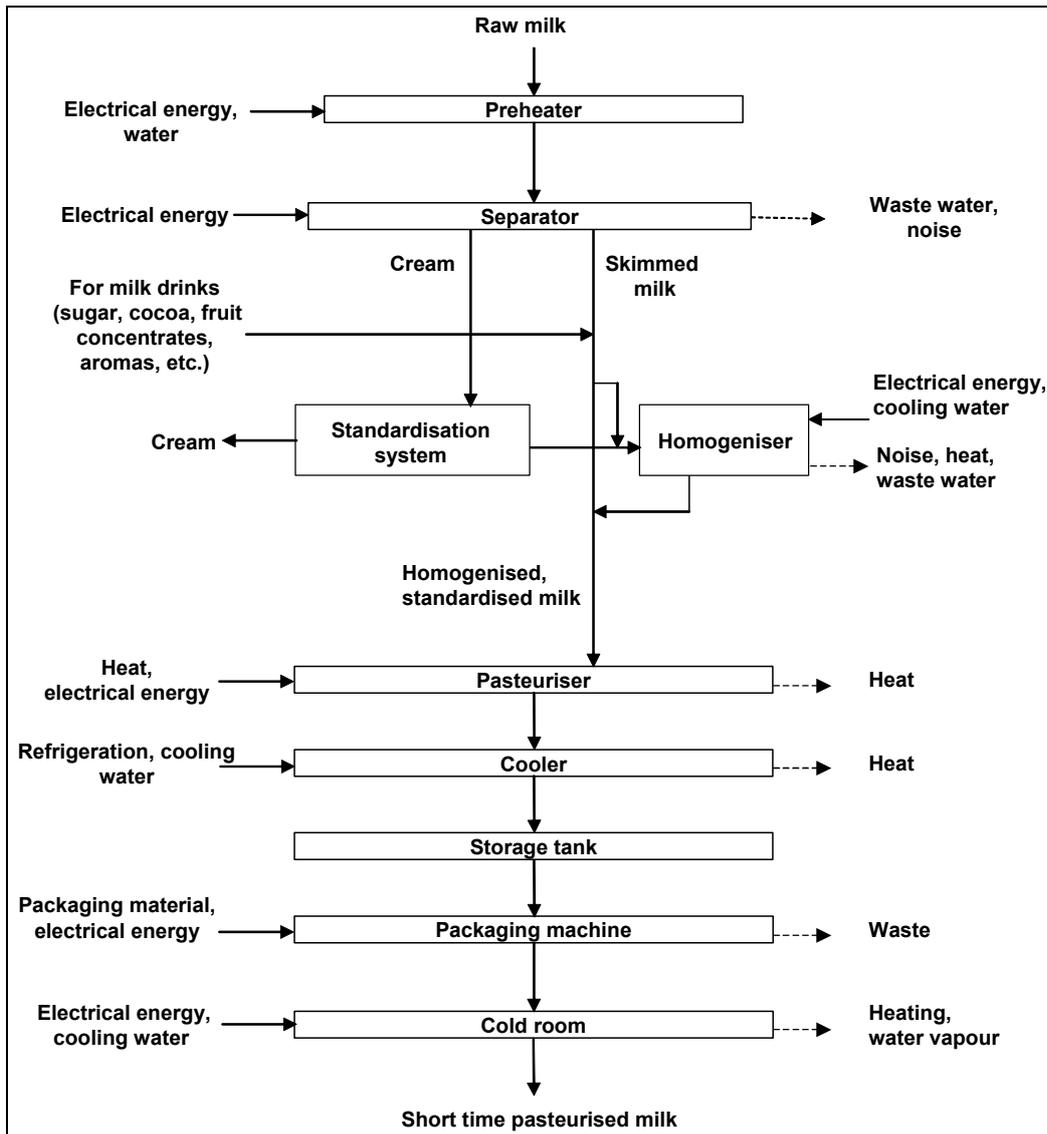
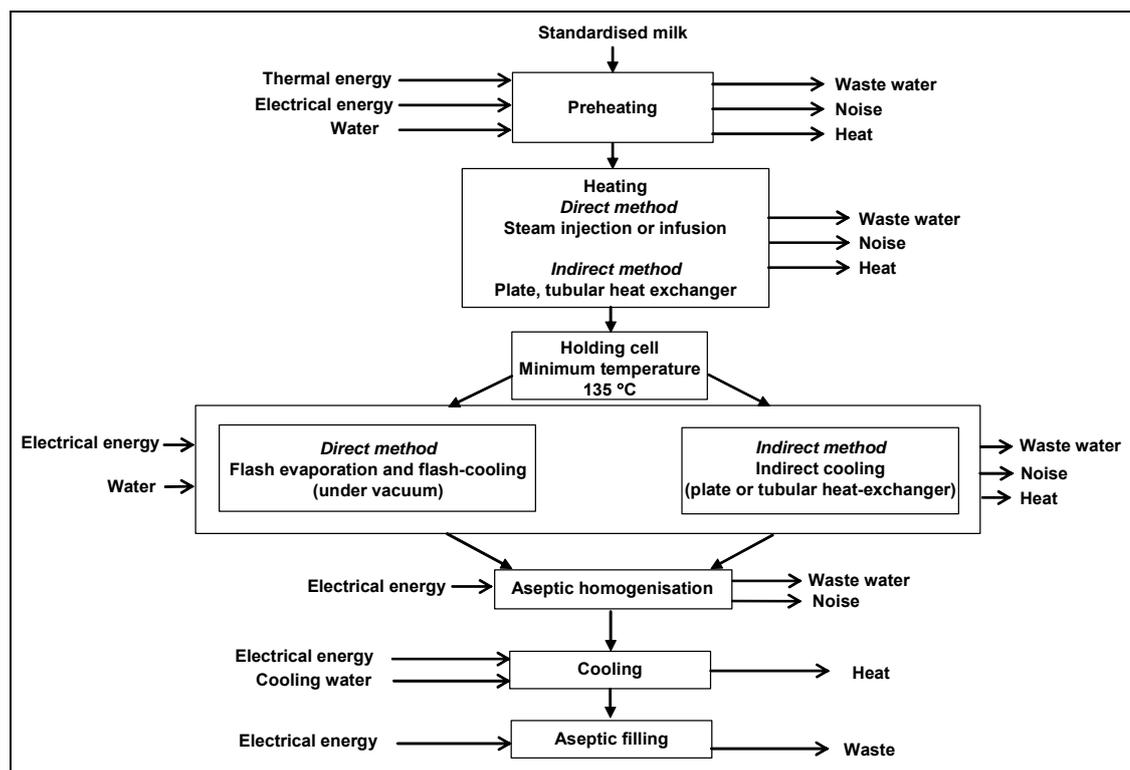


Figure 2.9: Short time pasteurised milk process [79, Italian contribution, 2001]

UHT or sterilisation is used to increase the shelf-life of the product. Continuous UHT at a minimum of 135 °C for one second is carried out. This can be done in two different ways. Heating it indirectly, using heat-exchangers with various types of plates and pipes or in two stages, i.e. first heating the milk indirectly to approximately 80 °C and then heating it directly by mixing steam and milk. The ratio of the weight of steam and milk used is approximately 1:10. If direct heating is applied immediately after the heat treatment, the milk is then cooled by expanding it under a vacuum to extract the steam mixed with the product in the sterilisation phase. This is also called flash cooling. The end temperature of the milk immediately returns to its level prior to mixing with the steam. Cooling by indirect exchange with a coolant or countercurrently with the incoming product, then follows. Figure 2.10 summarises the production of UHT milk.



**Figure 2.10: Production of UHT milk**  
[79, Italian contribution, 2001]

The heat treatment for long-life sterilised milk consists of two phases. The first phase is a continuous heat treatment or pre-sterilisation, similar to that described for UHT treatment. The second phase consists of the final treatment of the closed container after filling and sealing the pre-sterilised product. The second heat treatment generally takes place in an autoclave in batches or in a continuous retort at approximately 110 to 125 °C for 20 to 40 minutes with an end phase of sprinkler cooling. Long-life sterilised milk and other dairy products are packaged in closed containers such as plastic or glass bottles. Figure 2.11 summarises the production of sterilised milk.

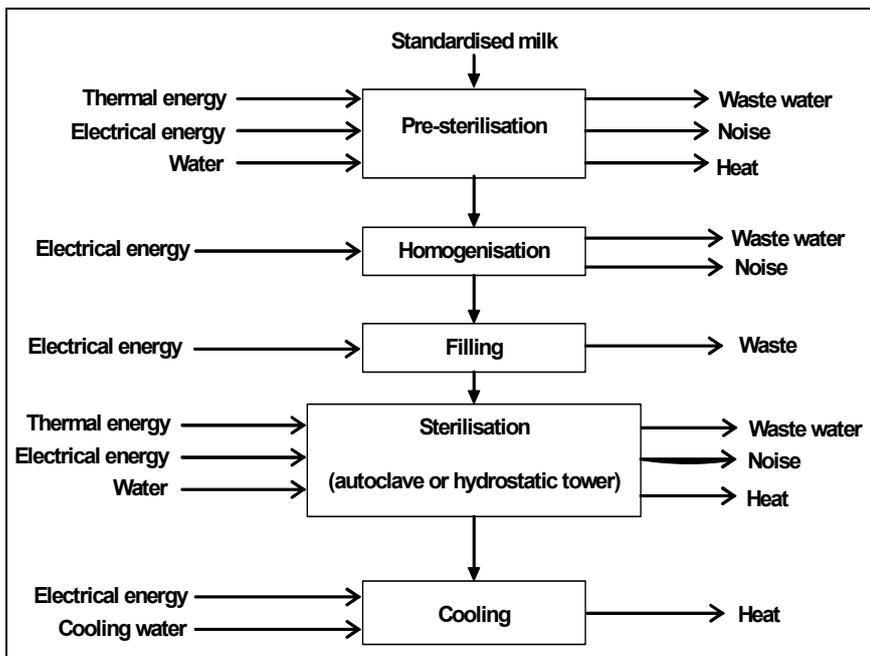


Figure 2.11: Production of sterilised milk  
[79, Italian contribution, 2001]

### 2.2.5.2 Condensed and powdered milk

The first stage in the production of condensed and powdered milk is the concentration of the raw milk. Homogenised milk is usually concentrated with evaporators. Falling film evaporators are generally used followed by a drying step using a spray drier (see Section 4.2.9). Alternatively, RO can be used to mechanically remove some of the water from the milk, without the application of heat. Electrical power is used to pump liquid through a semi-permeable membrane to increase the concentration of solids. Doubling of the concentration of milk and whey is common [39, Verband der Deutschen Milchwirtschaft (German Dairy Association), 2001]. The powder is typically agglomerated to improve reconstitution. Dry whole milk is susceptible to oxidative rancidity and may be packaged in a protective atmosphere to extend its shelf-life. These processes are shown in Figure 2.12 and Figure 2.13.

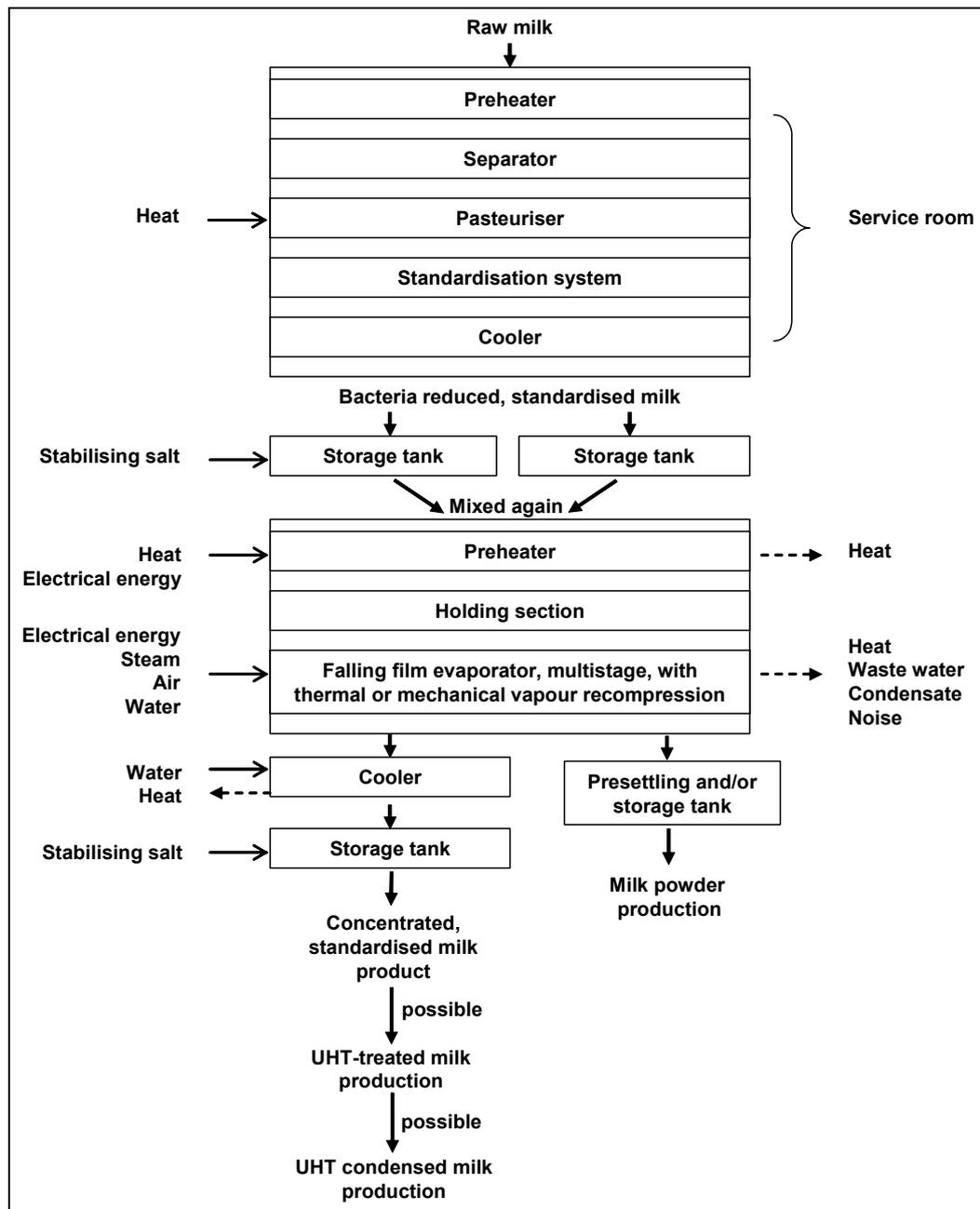


Figure 2.12: Flow sheet of processes for condensed products (e.g. UHT condensed milk) and intermediate products (e.g. milk concentrates)  
 [9, Verband der Deutschen Milchwirtschaft (German Dairy Association), 1999]

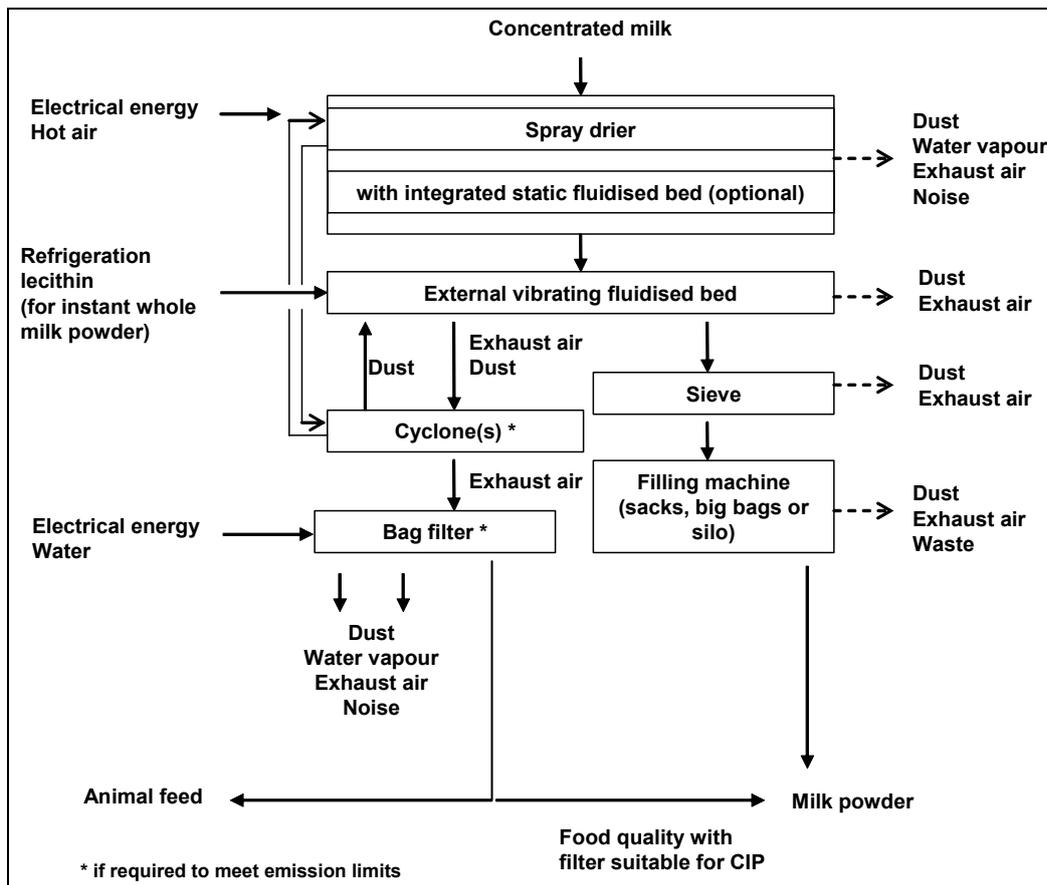


Figure 2.13: Flow sheet of powdered milk production [9, Verband der Deutschen Milchwirtschaft (German Dairy Association), 1999]

### 2.2.5.3 Butter

Butter is produced from cream which is centrifugally separated from pasteurised milk. The cream contains around 35 to 40 % milk fat. The process is basically a mechanical one in which cream, an emulsion of oil in water, is transformed to butter, an emulsion of water in oil. This is achieved by a process of batch or continuous churning. Cream is rapidly chilled and held at that temperature for a set period in a process known as ageing. The cream is then subjected to churning and working. Churning agitates the cream to partially break down the oil in the water emulsion until fat globules bind together to produce butter grains. The liquid phase called buttermilk is removed and the butter grains are washed in water. Salt may be added before the working stage of the process begins. This involves slow agitation of the grains, subjecting them to a kneading and folding action. The butter is packaged and stored, typically in chilled or frozen storage. A number of continuous techniques are available such as methods in which cream is subjected to high speed churning and continuous working. Figure 2.14 summarises continuous buttermaking.

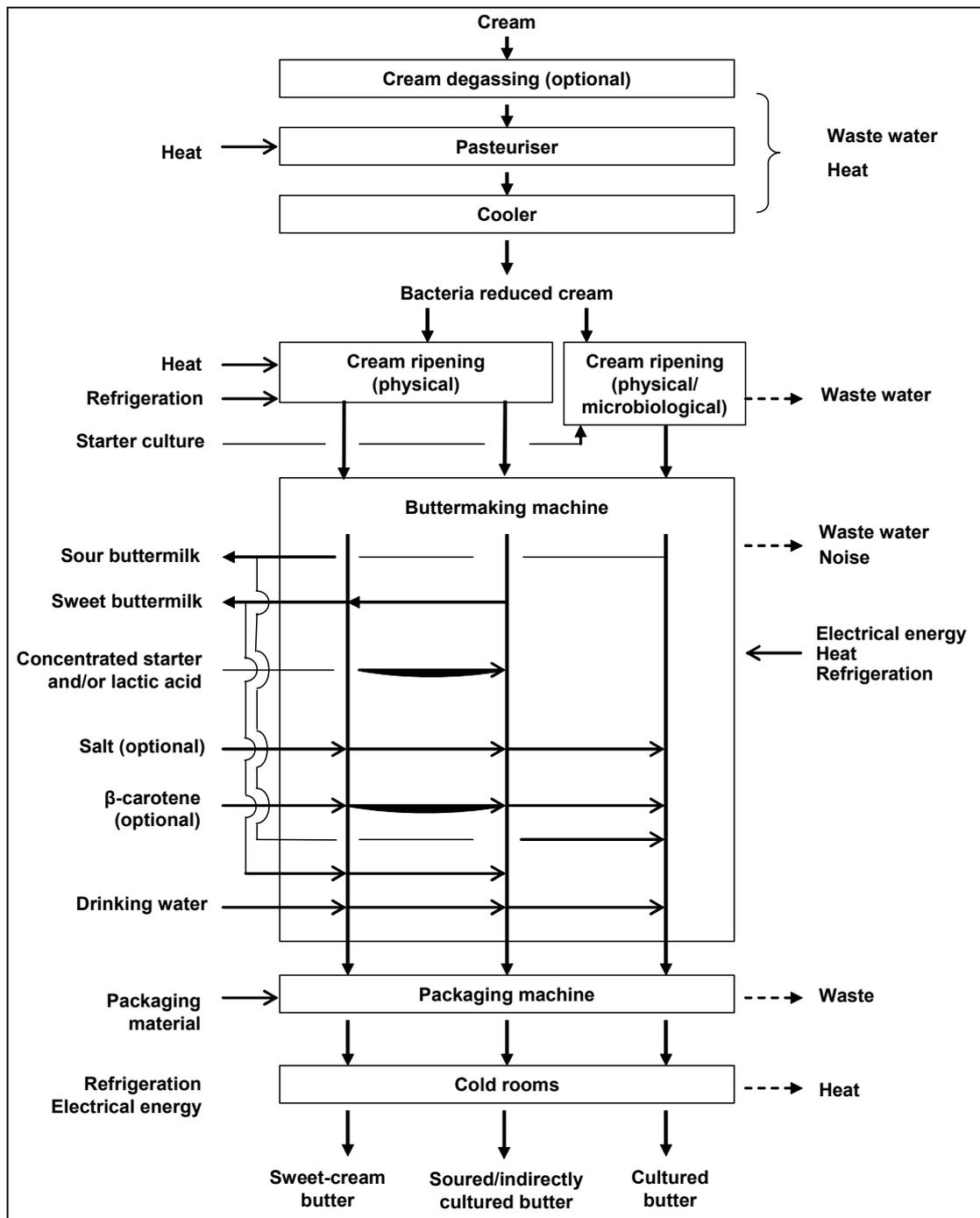


Figure 2.14: Continuous buttermaking  
[9, Verband der Deutschen Milchwirtschaft (German Dairy Association), 1999]

#### 2.2.5.4 Cheese

There are a very wide range of cheese varieties and many subtle differences in processing methods. In general, however, the following process steps apply; production of a coagulum through the action of rennet and/or lactic acid, separation of the resulting curds from the whey, and manipulation of the curds to produce the desired characteristics of the cheese.

The traditional manufacture of cheese is a manual process but modern processes are highly mechanised. Starter cultures are added to the milk to produce lactic acid and rennet is then used to coagulate the milk protein. The curds and whey are separated and the curds washed and cut into cubes. Texturising of the cheese involves compressing and stretching the curds and can be carried out in tower systems. The curd blocks are milled, salt is added, and the curds are pressed. Pressed cheese is wrapped to protect it against moisture loss and mould growth during storage. Cheese is matured to develop flavour and texture in temperature and humidity controlled stores, with regular turning of the cheese surface. Figure 2.15 shows a flow sheet of the manufacture of cheese.

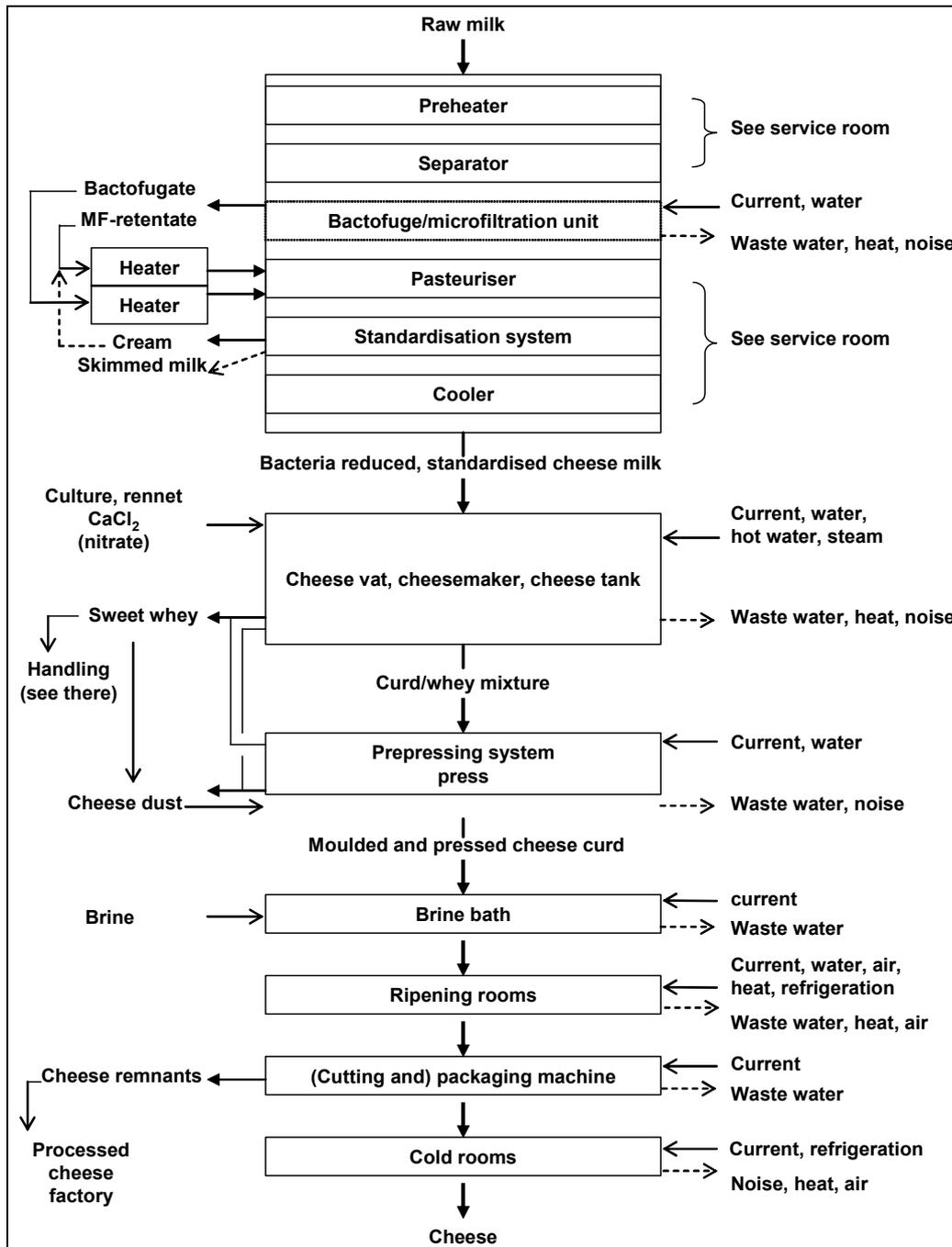


Figure 2.15: Manufacture of cheese  
 [9, Verband der Deutschen Milchwirtschaft (German Dairy Association), 1999]

A further process involves melting. Milled cheese and other ingredients are put into a processing kettle and heated to a temperature normally not less than 75 °C to ensure a complete pasteurisation of the processed cheese. Agitation during processing is important for a complete emulsification of the processed cheese. The temperature and duration of the process depends on the type of processed cheese aimed for and the nature of the raw cheese.

#### 2.2.5.5 Yoghurt

Yoghurt is a fermented milk product which differs from cheese in that rennet is not added and thickening occurs as a result of acidification by lactic acid bacteria. The main ingredients of yoghurt include milk; milk powders or concentrated milk or ultra-filtered milk, and stabilisers, such as modified starches. Most of the yoghurt produced is manufactured in bulk before the addition of fruit and/or flavourings.

The main steps in the manufacture of yoghurt are as follows. The fat and non-fat solids content of the milk is first increased by the addition of milk powders. Stabilisers may be added at this stage. The milk is then homogenised at a temperature of around 55 °C and heat treated at 80 to 90 °C for 30 minutes in a batch process, or 90 to 95 °C for 5 minutes in a continuous process. The heat treated milk is then cooled to around 40 to 43 °C and seeded with two starter organisms – *Streptococcus salivarius* subspecies *thermophilus* and *Lactobacillus delbrueckii* subspecies *bulgaricus*. Fermentation takes around 4 hours. At the end of the process, the product is cooled to 15 – 20 °C, using either tank cooling coils or, more commonly, tubular or plate heat-exchangers. Fruit and flavours are blended into the yoghurt which is then cooled to less than 5 °C and filled into pots ready for storage and distribution. Figure 2.16 shows the yoghurt production process.

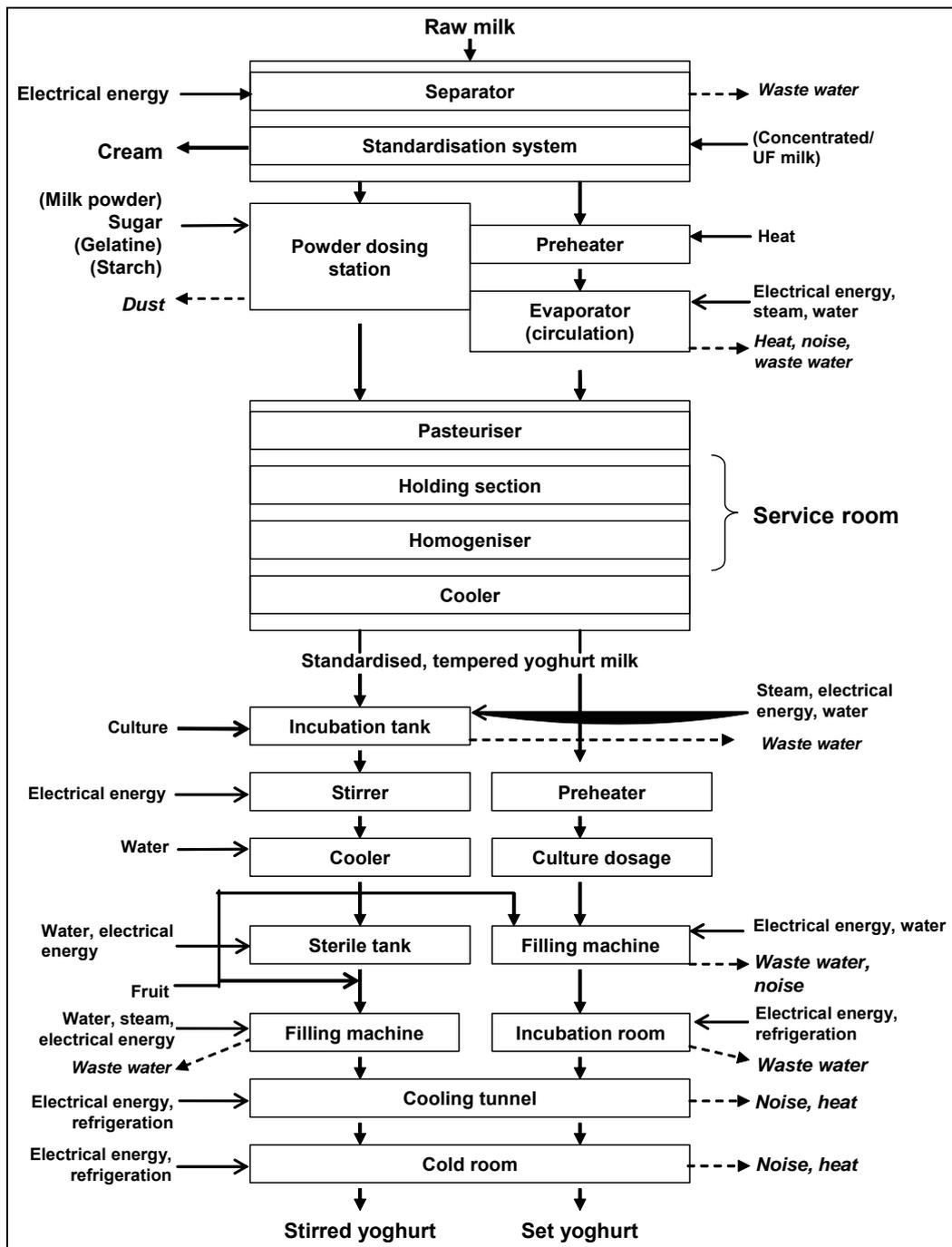


Figure 2.16: Yoghurt production [9, Verband der Deutschen Milchwirtschaft (German Dairy Association), 1999]

### 2.2.5.6 Ice-cream

Ice-cream is a dairy based product which typically contains 6 to 12 % fat, 7.5 to 11.5 % non-fat milk solids, and 13 to 18 % sugars. Stabilisers, emulsifiers, colours and flavours are also added. Sugar is usually added as sucrose, and the non-fat milk solids are usually from skimmed milk solids. The fat source may be milk, cream, butter or butter oil. Most ice-cream contains vegetable fat. The ingredients are blended, heated to around 70 to 75 °C and homogenised. The mixture is then pasteurised by heating to 80 – 85 °C for 2 to 15 seconds before cooling and ageing by holding at chilled temperatures for 4 to 24 hours.

Colours and flavours are added at the ageing stage. Continuous freezers are used to rapidly freeze the ice-cream down to around  $-6\text{ }^{\circ}\text{C}$ , with compressed air being introduced into the ice-cream during the freezing process. The increase in volume due to the addition of air is known as over-run. The ice-cream is filled into containers and frozen further in tunnel freezers operating at  $-30$  to  $-40\text{ }^{\circ}\text{C}$ .

### 2.2.5.7 Whey

Whey is normally evaporated to a supersaturated solution with a total solids content of 60 to 73 % to produce lactose. In cooling down the solution, crystallisation starts and the crystals begin to grow. The crystals are removed from the liquid phase by centrifugation. Depending on the required grade, further purification or refining can take place by washing the crystals, or redissolving them and recrystallising them, followed by treatment with active carbon for the removal of any impurities.

### 2.2.6 Grain mill products

There are a number of cereals important as food sources. These include wheat, barley, maize, oats, rye and rice. Wheat and rye grain is milled into flour. Durum wheat is milled into semolina and is generally used to make pasta. Wheat is the prime ingredient used in the manufacture of products such as bread and biscuits. In some countries, rye is used for bread. Barley is mainly used for animal feed. Barley of a certain quality is processed to malt and then used, e.g. in brewing and distilling. Maize is used as a source of starch but also as an ingredient in breakfast cereals and snack foods. Oats are used for cereals, cakes, biscuits, and also for making crispbread. Rice, along with wheat and maize is one of the major cereals of the world and is the basic food for much of the world's population. Rice is pearled and sometimes precooked.

The wheat grain has three main components, the skin or bran, the embryo or germ, and the endosperm, which makes up the majority of the grain. The object of the milling process is to separate the endosperm with minimal contamination from the bran and germ. The main operations associated with flour milling are cleaning, conditioning, breaking, scalping, purification, reduction and dressing.

The incoming grain is transferred to bulk silos prior to further processing. Gas or heat treatment may be applied to prevent insect infestation. The grain is first washed by passing through a series of screening, scouring, brushing and aspiration operations. These processes remove extraneous matter such as other cereals, stones, metal contaminants, chaff, loosened bran layers, seeds and dust. After washing, the grain is conditioned to optimise the milling process. This involves dampening the grain by the measured addition of water, which immediately binds the kernels. Conditioning may be made by using steam. Conditioning has a number of functions, such as toughening the bran, and thereby improves the separation of the bran from the endosperm, allowing the endosperm to be reduced more effectively in subsequent stages of the process.

The conditioned grain enters the break system of the mill, which consists of pairs of corrugated rollers which revolve in opposite directions and at different speeds. Five sets of break operations are common, with the aperture gradually decreasing and the corrugation becoming finer between subsequent sets. The grain is split by the break-rollers and the endosperm is scraped from the bran. A screening operation known as scalping or grading is carried out after each break-roller. This operation separates:

- coarse particles which contain the remains of the grain and some endosperm which is yet to be recovered
- particles of intermediate size which contain chunks of endosperm which are called semolina or middlings, depending on their particle size and purity
- flour.

The semolina or middlings pass through a purification system consisting of sieving and air classification. This removes particles of endosperm with bran adhering for further treatment by finely fluted rollers elsewhere in the process. The semolina or middlings are then transferred onto reduction rollers, which are smooth and whose purpose is to crush the endosperm. As in the break section of the mill, there are a series of rollers and screening operations, so that flour is screened off whilst the coarser endosperm, retained on the sieves, passes to another set of reduction rollers to be further reduced in size. At the end of the reduction process, most of the endosperm will have been converted to flour, the coarse bran will have been removed and there will be a third stream of endosperm consisting of material containing fine bran which cannot be practically separated. There could be as many as 12 reduction stages in the process. Flour is normally passed over a final redresser at the end of the milling process or after bulk storage to remove any residual foreign bodies. Flour may be dried and classified by sieves into fractions. Practice varies in different MSs, e.g. in the UK, 25 % is bagged for delivery to bakers and other food manufacturers and 70 % is delivered in bulk, whereas in Portugal, the proportions are almost identically opposite.

Grains such as oats and barley, with a tightly adhering husk cannot simply be separated in a traditional wheat mill and are usually subjected to an abrasion process called pearling prior to milling.

### 2.2.7 Dry pasta

In modern pasta factories, the manufacturing process is continuous. Semolina is stored in silos. It is then sent by pneumatic conveyers to the production area. Semolina is sieved and then mixed with water to form dough. Semolina has a starting moisture content of 10 to 14 %. In the mixing operation, 22 to 30 kg of water is added per 100 kg semolina. The moisture content during mixing varies between 30 and 35 %, depending on the quality and the type of semolina, and the shape of the pasta being produced. The weight of semolina and the flow of water being fed to the process is continuously monitored and automatically regulated using microcomputers. At this stage in the process, it is important for the semolina to be well hydrated and in a uniform way, to maintain an equal consistency in the dough. This ensures the quality of the final product, e.g. by preventing brittleness, surface defects and poor cooking quality.

The final mixing operation is degassing in a vacuum mixer, which removes the air that has been introduced during the earlier mixing operation. This prevents oxidation of the semolina pigments, or of the egg, in the case of egg pasta and gives a shiny appearance to the product. The pasta is pressed, extruded or laminated, depending on the shape of the final product. This is carried out using a worm screw within a cylinder which is cooled from outside. This physical action also causes the hydrated proteins to interact to form gluten. The dough is extruded at pressures varying between 4 and 12 MPa through a bronze or steel die corresponding to the shape of the product. If the holes of the die are faced with Teflon, a smooth pasta is obtained, otherwise a pasta of rough appearance is produced. The pasta comes out of the die with a moisture content of about 30 %. The final moisture content should not exceed 12.5 %, to achieve the required specific consistency and enable a long shelf-life. This, and the cooking characteristics of the product, are achieved by drying the pasta in three distinct stages, known as pre-drying, central drying and final drying.

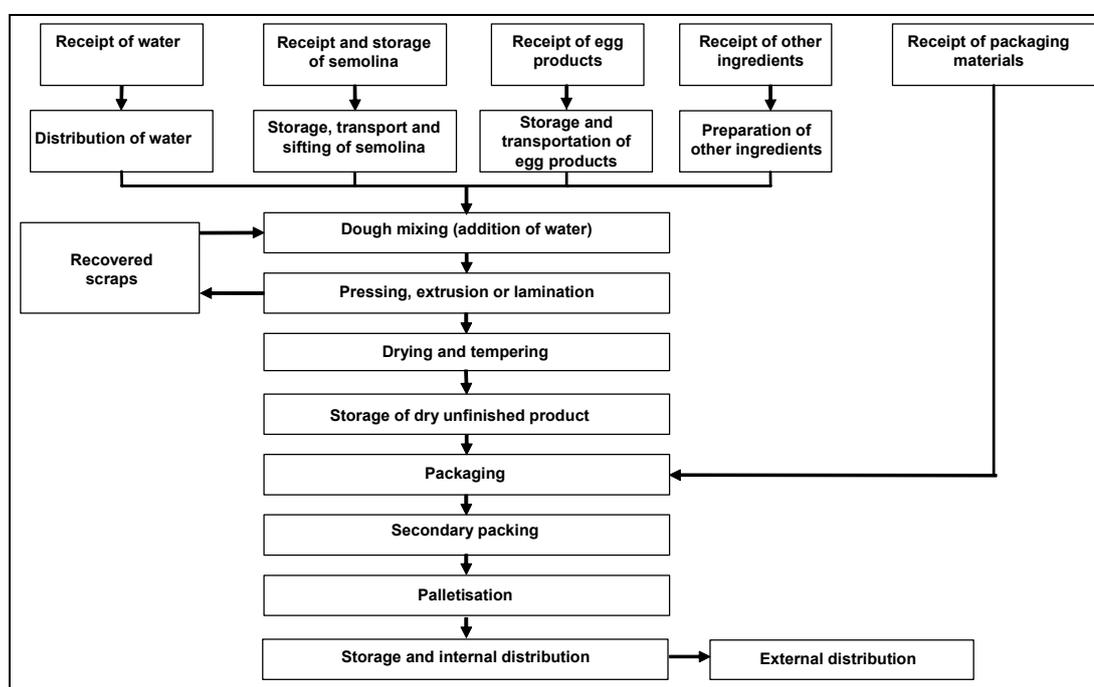
Pre-drying comprises intensive ventilation to create a thin dry surface area which prevents the various pasta pieces from crushing or sticking to each other. Filtered air, devoid of dust and other impurities, is used. The temperature and humidity are both controlled to regulate the evaporation rate and prevent fragility, which happens if the pasta is dried too quickly. Formation of mould occurs if the process is too slow. Pre-drying takes 10 to 60 minutes and removes 15 to 20 % of the moisture present. This phase is not needed for long pasta since it is transported hanging from canes, and there is less danger of sticking and deformation.

Central drying is achieved by another hot airflow repeated after alternate phases of rest, known as tempering. Tempering allows the moisture remaining inside the pasta to be redistributed uniformly on the surface. In some pasta production lines, tempering is not needed. During central drying, up to 60 % of the moisture present is removed.

During final drying, the pasta is passed through several chambers, where it is subject to a powerful hot and dry airstream that removes up to 25 – 30 % of the initial moisture. This last phase is carried out at variable temperatures, which may exceed 80 °C. The temperature and the duration of the cycle vary according to the type of technology employed and the type of pasta required. Depending on the kind of production line, drying can be performed in separate chambers or in an uninterrupted tunnel, subdivided into three continuous stages.

The design of production lines vary depending on the shape of the pasta, e.g. lines for long pasta have spreaders to hold the strips straight and to keep them apart, and lasagne, nest and tangle pasta lines have special layouts and lines producing short pasta so have initial kneaders. At the end of the drying line, a cooling chamber lowers the temperature of the dried pasta before it is conveyed to storage silos. The pasta is then transferred for primary packaging, using sheets of plastic or cardboard boxes, before secondary packaging, palletisation and storage prior to dispatch. The dry pasta production process is summarised in Figure 2.17.

For egg pasta, the production process is the same as that for other dry pastas, except for the presence of an automatic measurer for the egg mixture [150, Unione Industriali Pastai Italiani, 2002].



**Figure 2.17: Summary of the dry pasta production process**  
[183, CIAA-UNAFPA, 2003]

## 2.2.8 Starch

Starch is a high molecular mass carbohydrate produced naturally by plants as an energy reserve. Starch and its derivatives are used in several sectors including food, feed, paper and board, textiles, pharmaceuticals and cosmetics. Purified starch is usually a white powder. Starch and its derivatives can be used for thickening, binding, gelatinising, colouring, anti-crystallising and for sweetening in the food industry. Physically or chemically treated or modified starches are produced to specifically enhance some functional properties. Hydrolysis of starch by acid or enzymes yields a variety of sugar syrups called liquid sweeteners, which can also be dried, and be used in confectionery, drinks, baby food, dairy or baked products. Incomplete hydrolysis yields a mixture of glucose, maltose and non-hydrolysed fractions. Germ is a co-product of the manufacture of starch, and can be used to produce oils. Other co-products are fibre, gluten and de-fatted meal which are all used or sold on for other uses, including animal feed.

The main raw materials used in Europe for the production of starch and its derivatives are cereals, i.e. maize, wheat, barley and rice, and potatoes of dedicated varieties. Each installation is usually technically dedicated to one raw material [10, Environment Agency of England and Wales, 2000, 84, European Starch Association, 2001]. Only starch production from maize, wheat and potatoes is described in this document.

### 2.2.8.1 Maize starch

The commercial separation of pure starch from maize is achieved by a wet milling process which is generally considered to be efficient. The process is operated as an enclosed system in which process water is re-used in a closed circuit. The addition of fresh water is limited to one point in the production process.

The raw material is washed using aspiration and screening to remove dust, chaff, broken grain, cobs and other extraneous material. The maize is soaked in water with sulphur dioxide (SO<sub>2</sub>) or sodium bisulphite (NaHSO<sub>3</sub>), for around 36 hours, in a process known as steeping. This removes solubles in the maize, softens the kernel to improve separation of the various components and reduces microbial activity. After steeping, the maize is passed through several grinding and separation operations until only starch and gluten remain. The grain is first ground coarsely and the germs are removed from the coarse grist. After removing the germ, the grist is finely ground and fibre is removed through a screening operation. Starch and gluten are separated, typically using centrifugal methods. This raw starch is washed with drinking water, using a countercurrent flow, in a series of four to six centrifuges. At one end, raw starch is the input and process water is the output and at the other end, refined starch is the output and fresh drinking water is the input. The starch, which at this stage is called refined starch, is then dewatered and dried. Refined starch is typically 99 % pure and 85 – 88 % dry solids. Native starch is refined starch, before physico-chemical modification. The gluten and fibre are collected separately as co-products. An example of a maize starch extraction process is shown in Figure 2.18.

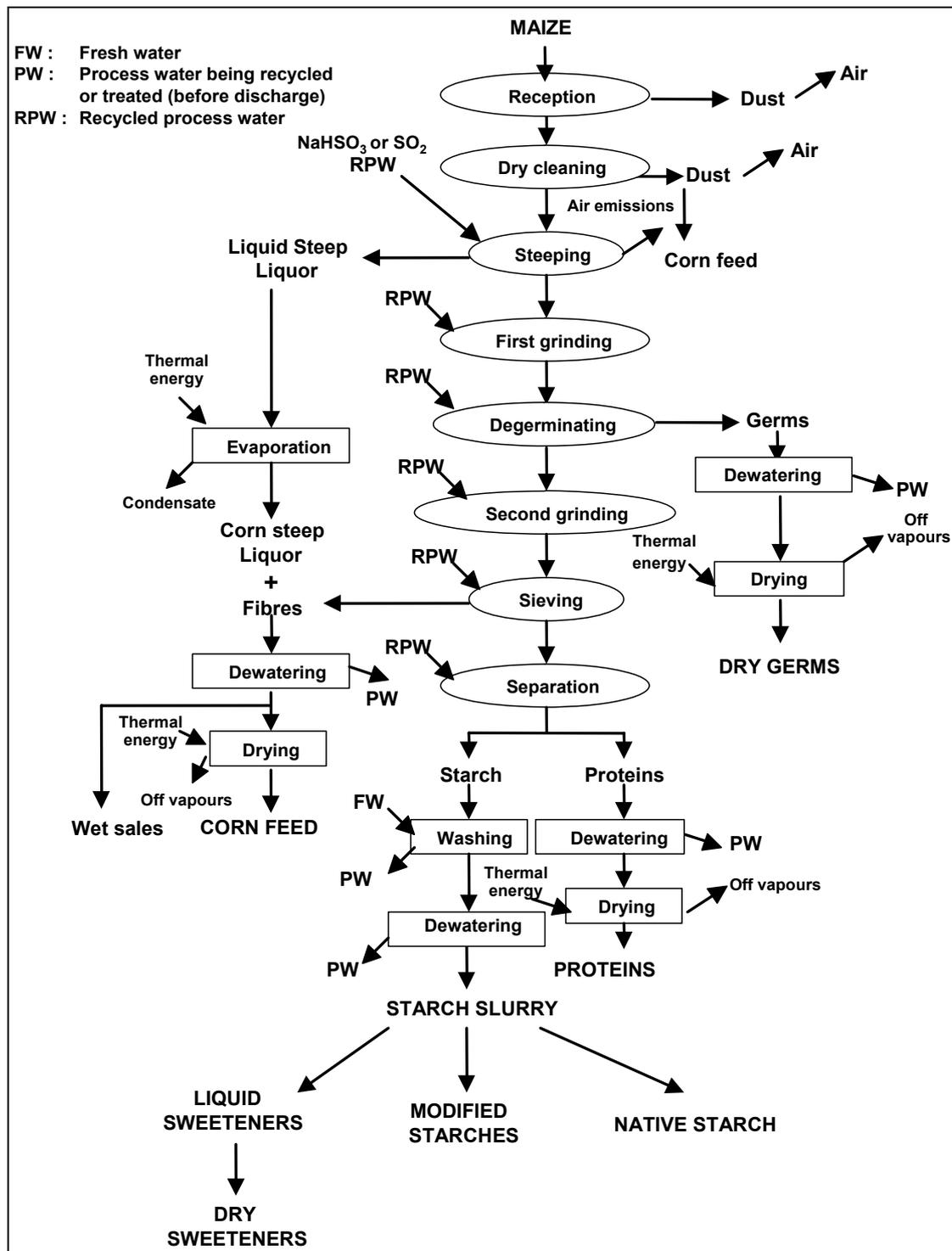


Figure 2.18: An example maize starch production process [84, European Starch Association, 2001]

### 2.2.8.2 Wheat starch

The commercial separation of pure starch from wheat is achieved by a two-phase process. In the first phase, the wheat kernel is ground or converted into wheat flour by a dry milling process. The second phase then separates the ground wheat or the wheat flour into its separate components, i.e. starch, gluten, solubles and eventually fibre, by a wet separation process. The process is operated as an enclosed system in which process water is recycled in a closed circuit. Fresh water is used at some stages of the process. An example of a wheat starch extraction process is summarised in Figure 2.19. The process of washing raw wheat starch to produce refined starch is the same as that for maize starch (see Section 2.2.8.1).

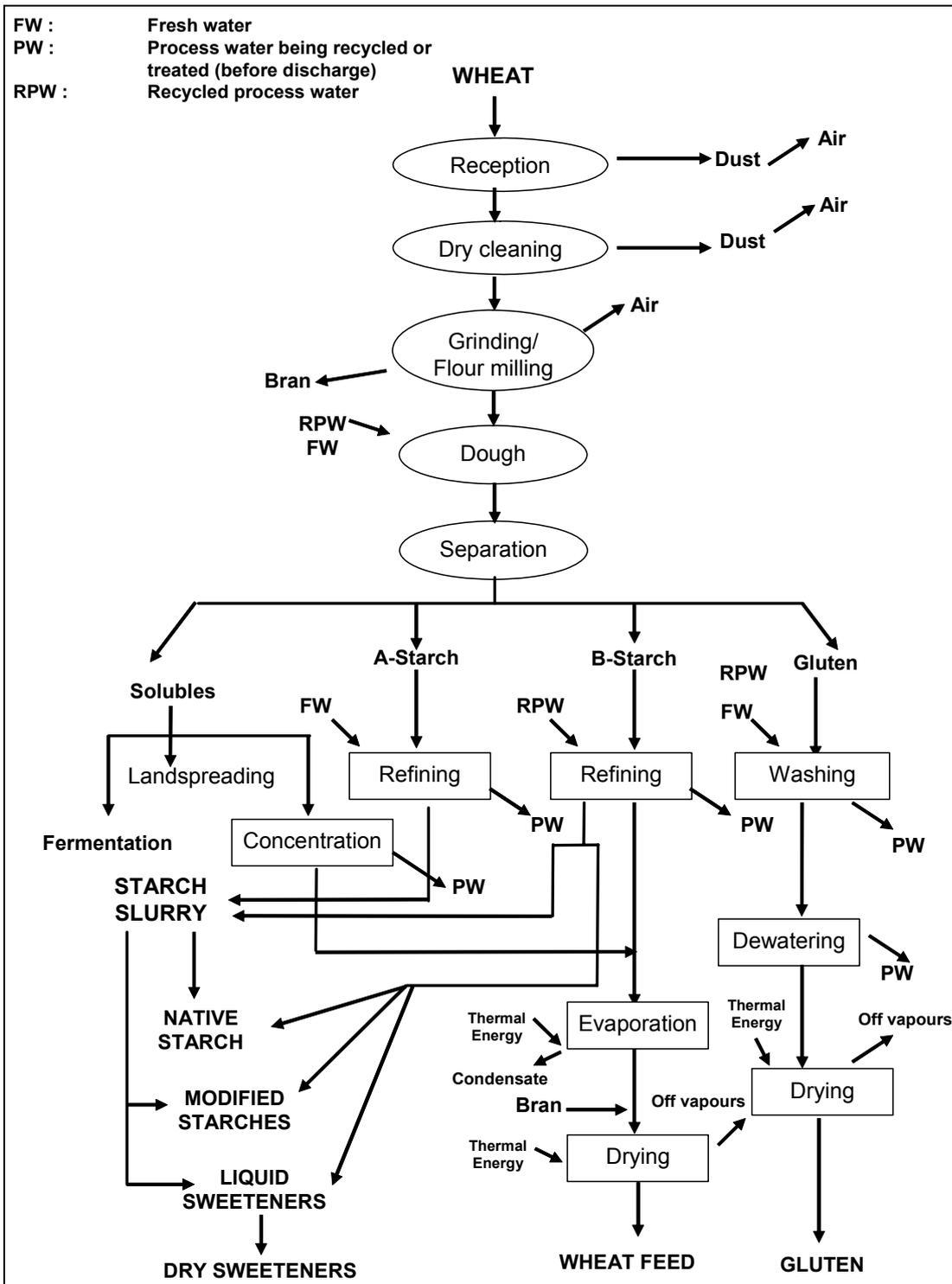


Figure 2.19: An example wheat starch production process [84, European Starch Association, 2001]

2.2.8.3 Potato starch

Starch is extracted from potatoes by a wet process. This involves the disintegration of the tuber into a pulp, which is then dewatered and dried to produce the final product. Fibre and fruit juice are also generated from the tuber. An example of a potato starch extraction process is summarised in Figure 2.20. The process of washing raw potato starch to produce refined starch is the same as that for maize starch (see Section 2.2.8.1).

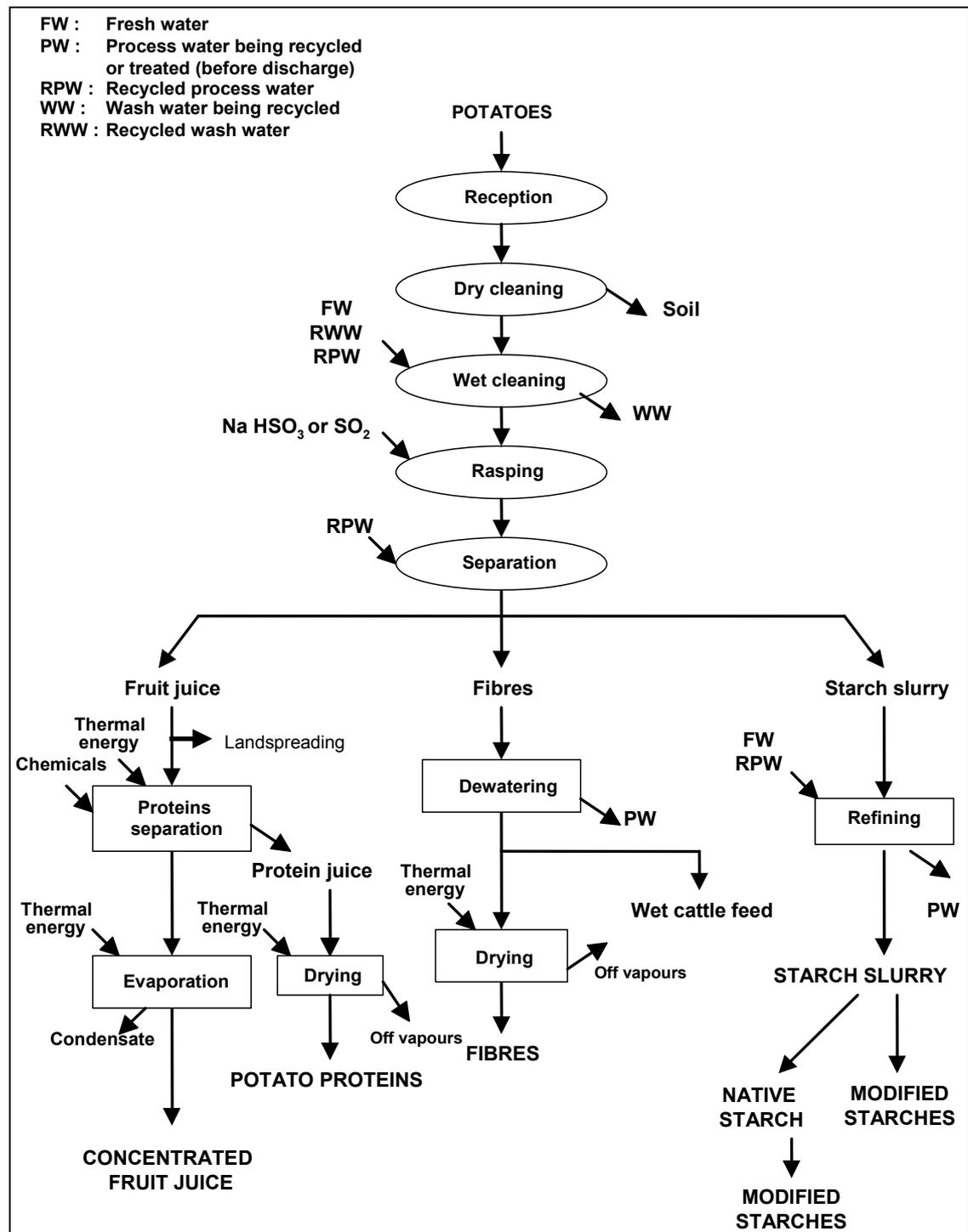


Figure 2.20: An example potato starch production process  
 [84, European Starch Association, 2001]

### 2.2.8.4 Sweeteners

Starch slurry is the starting raw material for the manufacture of sweeteners or sugar syrups. These are produced by the action of acids, enzymes or a combination of both, however enzymes are more commonly used. In a typical process, the starch slurry is heated to gelatinise the starch and then mixed with acids and/or enzymes and reacted in different liquefaction, saccharification and isomerisation reactors. The temperature is then raised to around 140 °C. Conversion of the starch only takes a few minutes. The mass is neutralised and after several stages of purification, i.e. separation of insolubles, demineralisation and decolourisation, the product obtained is evaporated. The liquor is usually filtered and treated with active charcoal or ion exchange resins to remove colour, ash and other minor impurities, e.g. minerals. The liquid sweetener resulting can be sold as such, or dried, or crystallised to produce dry sweeteners.

### 2.2.8.5 Modified (physical/chemical) starch

The properties of native starch can be changed to produce modified starch. Modification can be carried out with chemicals, enzymes or physically. The chemicals added can either be dry or wet, so final drying may be necessary. In the dry chemical modification process, dewatered and dried native starch is used. The product is chemically modified starch. In the wet process, the starch slurry, or the re-slurried native starch, is fed directly into the reactor with chemicals and the reaction takes place in liquid form. The resulting slurry can be washed and/or dewatered prior to drying. The product is a physico-chemically treated or modified starch.

### 2.2.9 Animal feed

The compound feed industry consists of two distinct sectors, i.e. animal feed and petfood. Animal feeds are predominantly dry, while petfoods often have a significant moisture content. In both sectors, the manufacturing process involves the blending of a range of ingredients such as cereals, protein sources, vitamins, minerals, fats and oils, to produce nutritionally balanced foods.

By far the most important moist petfood ranges are those for dogs and cats. These foods are classified according to moisture, packaging and processing systems, and include moist foods and semi-moist foods. In the UK, although moist foods currently comprise a major portion of the market, semi-moist foods are becoming increasingly popular. Moist foods have a moisture content of 60 to 85 % and are usually preserved by heating. Heat treatment may be applied before or after packaging. Moist foods can be subdivided into canned foods, premium moist foods, brawns and frozen meats.

#### 2.2.9.1 Animal feed and dry petfood

The main animal feed types are compound feeds. These consist of a variety of blended ingredients. The composition is varied depending on the type and age of the animal to be fed, but typically includes ingredients such as cereals, animal and vegetable proteins, fibre sources, minerals and supplements such as vitamins, antibiotics and other additives. Some of the ingredients are co-products and by-products of the FDM sector.

The raw materials are received at the feed mill and may be pneumatically conveyed or mechanically transferred to bulk storage silos. Some small ingredients which may be mixed in during the process, such as supplements, may be sent pre-bagged in appropriate quantities. Ingredients are weighed automatically in modern installations and transferred to holding bins prior to grinding, typically using hammer mills. After grinding, the ingredients are thoroughly mixed and any supplements are added. The blend may then be drawn off as meal or mash feed, or pressed to produce pelleted feed. More commonly, the blend goes on to be manufactured into feed pellets. Steam is injected into the feed in a process known as conditioning before being forced through holes in the pelletising die. The resulting pellets vary in size depending on the intended use. After this stage of manufacture, the pellets are dried and then cooled, typically in

coolers in which the pellets enter from the top and cool air is blown in from the bottom. To account for moisture loss during pelletising, drying and cooling, water may be added to some feeds, at the blending stage. The pellets are then either stored in bulk or packed. Some feeds may be coated in fat prior to packing.

### 2.2.9.2 Moist petfood

The raw materials used in moist petfoods are typically co-products of the FDM sector. These co-products must be fit for human consumption, although they would not typically be used for this purpose. Ingredients used include meat processing co-products, whole grain, ground cereals, flavourings, and vitamin and mineral supplements. Petfoods are designed to be nutritionally balanced to meet the needs of a particular type of animal.

### 2.2.9.3 Semi-moist petfood

The raw materials used in moist petfoods are typically co-products of the FDM sector. Ingredients commonly used include dry cereal sources, vitamin and mineral supplements and some meat slurries. The ingredients are blended, conditioned and extruded into small shaped pieces. The pieces are dried and fat or meat extracts may be sprayed onto the surface. This type of feed is often multi-component. After drying, various fractions manufactured in a similar way are blended to produce the finished feed. The feed is then packaged.

## 2.2.10 Bread

One of the main bakery products is bread. Bread includes several bakery products and the types vary significantly from country to country.

In **France**, about 80 % of bread is still produced in small bakeries. The most common traditionally eaten bread is the baguette. It is produced with four basic materials, i.e. flour, water, salt and yeast. It represents more than 50 % of French bread production. Other French speciality breads include fine wheat bread or “pain de gruau”, viennese bread, and biscottes [87, Ullmann, 2001].

In **Germany**, baked products are divided into two types. The production of bread allows a maximum of 10 parts sugar and/or fat to 90 parts flour. Products with more than 10 parts sugar and/or fat to 90 parts flour are called fine bakery wares or “Feine Backwaren”. Bread is divided into five main groups:

- wheat breads, at least 90 % wheat
- mixed wheat and rye breads, at least 50 % wheat
- mixed rye and wheat breads, at least 50 % rye
- rye breads, at least 90 % rye
- bread specialities.

Each of the first four groups were established based on the proportion of wheat and rye in the formula. These groups are further classified into subgroups according to the type of milled raw materials used, i.e. low extraction flour bread, meal bread, and wholemeal bread. Speciality breads can also be prepared. These contain, e.g. nonbread grains, such as oat, barley, rice and maize; raw materials of plant origin, such as oilseeds, germs and raisins, materials of animal origin, e.g. milk, butter, yogurt and whey. Otherwise they may be produced by using special baking techniques, e.g. a wood-heated oven; steam oven or stone oven. From the total German bread consumption, about 15 % is eaten as small rolls and its consumption is increasing. Recently, the so-called nonbread grain breads have become very popular. Also the production of dark breads such as wholemeal flour breads is on the increase [87, Ullmann, 2001].

The typical UK sandwich bread has a high volume, soft texture, very fine porous crumb structure and is also characterised by long shelf-life properties. Speciality breads comprise germ breads with the addition of 10 – 25 % wheat germs and high protein breads with wheat gluten, milk, or sometimes soy protein. Malt bread produced in the UK is a sticky, sweet, dark loaf that might also contain dried fruit pieces. UK rye bread is usually made from a 50:50 mixture of white wheat flour and rye flour [87, Ullmann, 2001].

Bread is made by combining flour, water, salt and yeast. Wheat is the most important cereal grain produced and traded in the world for the production of bread and other baked products. Commercial production of bread may also involve the addition of preservatives and additives to improve flavour, texture and prevent microbiological growth. Production of most baked products containing wheat flour begins by mixing the ingredients to form a dough. Incorporation of air during dough mixing is necessary to achieve a baked loaf of good volume, structure, and texture. As dough becomes cohesive, it starts to incorporate air and, thus, decreases in density.

After bulk fermentation, the dough is divided into individual loaf-sized pieces, and then given time to allow the dough to relax before moulding. The moulding operation is essentially sheeting followed by curling, rolling and application of pressure. As the dough is sheeted, i.e. passed between rolls to be flattened during the various processes, it must be sheeted in different directions. Continued machining in one direction would align the protein fibrils and result in a dough that was strong in one direction but weak in the direction of a 90° angle to the sheeting. After being moulded, the loaf is ready for proofing. This is usually accomplished at 30 to 35 °C and at 85 % relative humidity. Because the dough now has only limited viscous-flow properties, it fills the pan by expansion. Proofing usually takes about 55 to 65 minutes; the dough increases greatly in volume. After proofing, the dough is ready for baking.

Baking times and temperatures and baking temperature profiles vary largely, depending upon the type of bread. For example, a wheat bread is usually baked for 35 to 40 minutes at 220 to 230 °C. In the UK, baking normally takes place at around 220 to 270 °C for 21 to 30 minutes. Heat is transferred by direct or indirect heat to the loaf. The most common energy source is the combustion of natural gas, although electricity may also be used. Combustion gases and volatiles from the oven are released via a stack. After cooling, the bread may be sliced before being wrapped ready for distribution.

Typical methods for making bread are the straight dough, sponge dough, sour dough, and Chorleywood process.

In the straight dough process, the dough is allowed to ferment for 2 to 3 hours. After fermentation, the dough is divided into loaf sized pieces, rounded into a ball, given an intermediate proofing time of 10 to 20 minutes, and then moulded and panned.

In the sponge dough process, a sponge is prepared from approximately 65 % flour, water, and yeast. The sponge is only mixed enough to have a uniform mixture and then allowed to ferment for 3 to 4r hours. After fermentation, the sponge is returned to the mixer and mixed with the rest of the formula ingredients. At this stage, the dough is mixed to optimum development. After mixing, the dough is allowed to relax for 15 to 20 minutes.

Utilisation of the sour dough process is the traditional leavening method in bread making. Bread doughs containing higher proportions of flour or meal require more acidification than is generally achieved by a sour dough process. During sour dough fermentation, a typical microflora develops that includes lactic acid bacteria, *lactobacilli*, and yeasts. Various sour dough processes, such as multi, two and single-stage varying from 2 hours up to 24 hours, were designed to increase the growth of yeast and lactic acid bacteria to give the final sour dough proper acidity, especially the lactic acid/acetic acid ratio, and achieve the desired dough consistency. Often baker's yeast, *Saccharomyces cerevisiae*, is added to accelerate the leavening process. Consequently, proof time of sour dough bread is often long, in the order of several hours. For the production of rye bread, acidification is required.

In the UK, the majority of commercial bakers employ the Chorleywood process. In this process, dough mixing and development take place in a single operation in the presence of an oxidising agent such as potassium iodate, potassium bromate, or ascorbic acid. This process requires a high quality wheat flour with a protein content of 12.5 % dry matter together with a high level of starch damage and hence high water absorption. An oxidising improver, fat or emulsifier, and extra water and yeast are mixed in at this stage. The whole mixing and development process lasts between 2 to 5 minutes. All short time systems require high levels of oxidants. The dough ingredients are mixed together with an intensive energy input and transferred to a hopper which is sometimes sprayed with oil. The dough is divided into loaf sized pieces. A preliminary rounding is given to the dough at this stage. The dough is then allowed to rest, first proof, before being given a final moulding and normally placed into tins. The tins may be sprayed with oil before filling. The dough is allowed to ferment a second time, second proof, and may be cut before baking.

## **2.2.11 Confectionery**

### **2.2.11.1 Biscuits**

The principal ingredients used in the manufacture of biscuits are wheat flour, fat and sugar. Water plays an important role in the biscuit making process but is largely removed during baking. Baked goods are normally decorated and ingredients like dried and wet fruit, cream and custard are utilised.

There are two basic dough types are hard doughs and short doughs. Whatever the dough type, the basic process steps involved in the manufacture of biscuits are dough mixing, formation of the dough pieces, baking, cooling and packaging. The methods used at each stage vary considerably depending on the product type. Raw materials are usually received in bulk and automatically metered into dough mixers. Small ingredients such as salt and sodium bicarbonate may be weighed and added by hand. The ingredients are blended and, in the case of hard doughs, mixed to promote a gluten network in the dough. In the case of short doughs, mixing is such that gluten development is deliberately limited. The formation of dough pieces varies depending on the biscuit type. Crackers and semi-sweet biscuits are cut from continuous sheets of rolled hard dough. Crackers require considerable processing as they are built up in a series of thin layers. Most short doughs are formed by rotary moulding, but soft doughs for biscuits are usually wire cut. The biscuits are baked, usually in tunnel ovens. The times and temperatures used vary depending on the product. Ovens may be direct or indirect fired, gas or electric. The baked biscuits are cooled and packed or transferred for secondary processing, e.g. layering of cream fillings. Crackers may be oil sprayed immediately after baking. Cooling is typically achieved by conveying the biscuits around the installation for a set time period.

### **2.2.11.2 Cakes**

The main ingredients used in the manufacture of cake are wheat flour, fat, eggs, sugar, milk powder, water flavourings and raising agents. Cakes are generally made using either the sugar batter or flour batter method. In the sugar batter method, the fat and sugar are creamed together and eggs are added in stages. Several alternate additions of flour and liquid are carried out throughout the mixing. In the flour batter method, the fat and flour are blended together. The eggs and sugar are whisked together and then blended into the fat and flour in stages. The required quantities of liquids are then added in small amounts as mixing progresses.

In continuous mixing systems such as the Oakes and Mondo cake mixers, the ingredients are given a preliminary mix and then fed in a continuous even stream, into the head of the mixer. "All in" high speed cake mixing is being increasingly used. In this method, all ingredients except fruit are added and a fixed amount of mixing is carried out. The fruit is then added in short bursts.

Batters are typically deposited into oil sprayed trays or continuous sheets for products such as Swiss rolls. After baking, the cakes are removed from the tins and cooled. The empty tins are cleaned, rinsed, dried and cooled.

### 2.2.11.3 Cocoa

Drinking cocoa typically consists of cocoa powder, vanillin, cinnamon, salt, cassia and other powdered spices. Raw beans are received and subjected to a series of washing operations to remove extraneous matter such as fibre, stones, grit, metal, bean clusters and immature beans. The latter two materials may be used for the manufacture of cocoa butter. The beans are roasted. Roasting conditions vary depending on the equipment and the desired product, but are typically in the range of 100 to 140 °C for 4 to 6 minutes. Whole beans or the separated nibs may be roasted.

Winnowing is the separation of the outer shell of the bean from the edible nibs and typically consists of cracking the roasted bean between rollers, followed by air classification to remove the shell fragments. The nibs are ground to produce a cocoa liquor whose particle size is further reduced by grinding mills, which are water-cooled. The particle size is important for the manufacture of chocolate drink but less important for chocolate since this requires some further refining. The liquor or nibs from roasted or unroasted beans are likely to be subjected to a process known as alkalisation which increases the dispensability of cocoa powder in milk or water when used in drinks. It is also used to modify the colour of the cocoa. Only permitted acids, alkalis and emulsifiers may be used for this process.

Cocoa powder is produced by the hydraulic pressing of cocoa liquor to express cocoa butter and to reduce the fat content of the press cake to the desired level. The expressed cocoa butter is used in the manufacture of chocolate. The press cake is pulverised to produce a cocoa powder. The final product is then packaged.

### 2.2.11.4 Chocolate

The basic ingredients for the manufacture of chocolate include cocoa liquor, sugar, other sweeteners, cocoa butter, butter fat, milk powder, milk crumb and emulsifiers. The basic operations involved in chocolate production are the preparation and mixing of ingredients, refining and conching. Conching involves agitating the refined material to induce desirable physical changes in the final product and to improve the flavour. Chocolate production has traditionally been undertaken in a device called a melangeur, which accommodates all of the steps involved. Melangeurs are, however, being increasingly replaced by large specialist machines.

The refining stage in the manufacture of chocolate is intended to reduce the size of the particles of cocoa solids in the mix, thus ensuring that the mixture has a smooth consistency. This is achieved by passing the mixture through vertically mounted rollers which need to be water cooled to prevent distortions arising from frictional heating. A number of systems are available for conching, which is a specialised activity inducing complex changes in the chocolate. Processing milk chocolate in a traditional batch conch takes in excess of a day, whilst modern, continuous systems achieve the same result in around 4 hours. Finished chocolate is typically stored in bulk and must be tempered through a cooling and warming cycle before final use.

Chocolate products may be produced by casting the chocolate into moulds, followed by cooling and demoulding. Such methods may be used to produce solid chocolate blocks or shells, which may be hollow or filled with a confectionery such as fondant. Alternatively, liquid chocolate may be used to coat confectionery using units known as enrobers.

### 2.2.11.5 Boiled sweets

Boiled sweets are highly concentrated solutions of sugar, glucose syrup and sometimes invert sugar, with added flavourings. These are metered into continuous dissolvers. This mixture feeds cookers, of which there are a number of designs such as thin film, coil cookers or batch vacuum cookers. Water is rapidly evaporated from the syrup, which is then discharged and partially cooled due to evaporative cooling. The boiled sweet mass is transferred to water-cooled tables and acid, flavour and colours, are added to the partially cooled mass in a batch or continuous process. The mix is then transferred to forming machinery. The formed sweets are cooled and wrapped in moisture proof packs as rapidly as possible.

## 2.2.12 Sugar

Sugar (sucrose) is produced from two principal sources, sugar beet and sugar cane. Sugar beet tends to be grown in Europe and sugar cane in hotter climates [134, AWARENET, 2002] such as the West Indies, so it is not extracted in Europe. Sucrose is also available in a liquid form as an aqueous solution, in some cases all or partially inverted. Sugar crystals may be ground to make powdered or confectioner's sugars. Anti-caking agents such as maize starch are added to keep these sugars free flowing.

### 2.2.12.1 Sugar beet extraction

In general, the extraction of sugar from sugar beet and sugar cane is similar. The beets are cut into thin slices called cossettes. They are passed into a water-based countercurrent extraction apparatus called a diffuser and emerge as impure sugar juice and beet pulp. The fresh water used in the extraction process is actually condensed water from the subsequent evaporation steps together with recirculated water from the pulp pressing. The temperature inside the diffuser is 68 to 72 °C.

Three types of diffusers are used. Horizontal diffusers are large revolving drums, separated into cells by a helix attached to the interior surface. As the drum and helix revolve, the juice, which stays at the bottom of the vessel, is transported countercurrently to the cossettes, i.e. the exhausted beet pulp leaves the diffuser at the same end where the fresh water enters. Vertical diffusers are composed of an extractor with two main and distinct parts, i.e. the countercurrent mixer and the extraction tower. The tower is a 14 to 20 metres high cylinder. Inside the tower, a tubular shaft rotates slowly. Special helicoidal steel pieces, or flights, are fitted on the shaft and move the cossettes upwards. The juice and the cossettes move countercurrently. Slope diffusers consist essentially of a U-shaped sloping vessel in which two overlapping screws with opposite pitches rotate. Fresh cossettes fall from a conveyor belt into the lower end. The cossettes are transported upwards by the two screws to a paddle wheel, which lifts the exhausted cossettes out of the extractor. Fresh water is introduced at the upper end and the sugar juice leaves the extractor through a screen at the lower end.

The crystallisation process takes place in vacuum pans in which the juice is boiled under vacuum to minimise the temperatures involved. The growth of the sucrose crystal only involves sucrose and water. The non-sugars contained in the sugar juice are not incorporated into the crystal structure, instead most of them remain in the liquid phase while some are released to the vapour phase. The sugar crystals are removed from the liquid phase by centrifugation.

Sugar to be stored in silos must be dedusted and cooled to the storage temperature. This is carried out in a sugar cooler, which is a device in which warm and dried sugar is intensively aerated by cold filtered external air to cool the sugar to the storage temperature, approximately 20 to 30 °C. The most common systems in use are typically drum or fluidised bed coolers with chilling systems that have a countercurrent or cross-current phase flow.

### 2.2.12.2 Sugar cane

Raw cane sugar is usually separated, purified and crystallised in the country of origin. The cane sugar, which is in a crudely refined state, undergoes final processing when transferred to the country of use.

### 2.2.12.3 Sugar refining

Raw sugar is typically a minimum of 96 % sucrose. The impure crystals, with adhering molasses, are blended in a saturated sugar solution to soften the surface molasses film which can then be removed by centrifugation. The partly processed sugar is dissolved in reclaimed liquors, i.e. light waters from the refining process. Carbonation, which is treatment with milk of lime and carbon dioxide, then follows. This produces a precipitate which contains impurities such as pectins and proteins and removes suspended impurities such as waxes, gums and starches. The sugar syrup is filtered and decolourised using ion exchange resins and activated carbon to produce a fine liquor, which may be sold as a finished product or passed on for crystallisation.

The fine liquor is concentrated by evaporation to produce a syrup of around 60 – 70 % solids, known as thick juice. The juice is filtered and transferred to vacuum pans. When the liquor is slightly supersaturated, the pan is seeded with fine icing sugar to initiate crystallisation. The mixture is centrifugally separated to extract crystalline sugar, which is dried, conditioned for packaging or bulk loaded. Each pan boiling yields around 50 % of the available sugar.

The liquor separated during centrifugation, also called jet, is re-boiled for further extraction. Three boilings yield white sugar. A fourth boiling yields off white industrial sugar. Jet four, together with liquor from blending, goes to a recovery house for three further boilings to produce brown sugars which go back to the start of the refining process and are treated as raw sugar. Various intermediary products from jets one to four and the corresponding syrups from recovery and boiling are sold as the starting materials for syrups such as molasses and treacle. Molasses are sometimes used in animal feed, alcoholic fermentation and a number of non-food products.

### 2.2.13 Coffee

Commercial coffees are grown in tropical and subtropical climates at altitudes of up to around 1800 metres. Coffees from different producing regions possess different characteristic flavours. The main processing steps in the manufacture of roasted coffee are blending, roasting, grinding and packing. Instant coffee is produced from a water extract of roasted ground coffee. Roasting coffee beans and the production of instant coffee are energy intensive processes.

#### 2.2.13.1 Roasting coffee

Green coffee is received and sorted to remove extraneous matter. Coffees from different varieties or sources are blended before or after roasting. Roasting is usually carried out by hot combustion gases in rotating cylinders. The final bean temperature is around 200 to 220 °C. A water or air quench terminates the roast. Most of any added water is evaporated from the heat of the beans. Fluidised bed systems may greatly reduce roasting times from around 8 to 15 minutes to 1 to 3 minutes. Finished coffee is transferred to storage bins. Any residual foreign bodies are removed before grinding, usually by air classification methods. Most coffees are ground in steel cutting rollers which are scored, once longitudinally and once across the circumference. Cracking rolls break the beans before they are fed into a further series of rollers. For fine grinds, the coffee may pass into further sets of rollers, being scored on each subsequent pair of rollers and becoming progressively finer as the coffee travels through the system. Roasted and ground coffee in Europe is typically vacuum packed in flexible pouches of plastic-laminated foil.

### 2.2.13.2 Instant coffee

Instant coffee is subjected to similar processing, namely blending, roasting and grinding, although processing details such as particle size after grinding may differ. During extraction of coffee for the production of soluble coffee, water is the extracting solvent. The coarsely ground coffee is extracted in a battery of batch percolating columns. The process is operated semi-continuously with water in a countercurrent flow to the coffee, from the most extracted cell to the one just filled with fresh roast and ground coffee.

The extract is recovered from the fresh or least-extracted cell. One consequence of using high temperatures is that the system must be kept under pressure, so, the individual cells and associated pipework has to be designed accordingly. Once a batch of solids has been extracted, the exhausted cell is separated from the train and the spent grounds are discharged. At the same time, a cell containing fresh roast and ground coffee is added to the train. The extraction yield is expressed as the amount of recovered water-soluble dry solid content of roasted coffee as a percentage of roasted coffee (dry weight). Yields of 40 to 56 % are obtainable. Some manufacturers vacuum-concentrate the extract. The extract is dried, typically by spray-drying or freeze drying. The powder may be agglomerated to improve solubility. The final product is then packed into containers.

During the extraction of soluble solid matter from the roasted coffee, a large quantity of coffee grounds is produced in addition to the fluid coffee extract. These are utilised as fuel in special grate firing installations. The ground coffee is used, in balance with heating oil and natural gas, as a special fuel.

The following paragraphs describe the manufacture of instant coffee in an example installation which produces 18000 tonnes of green coffee per year. A diagram of the process is shown in Figure 2.21.

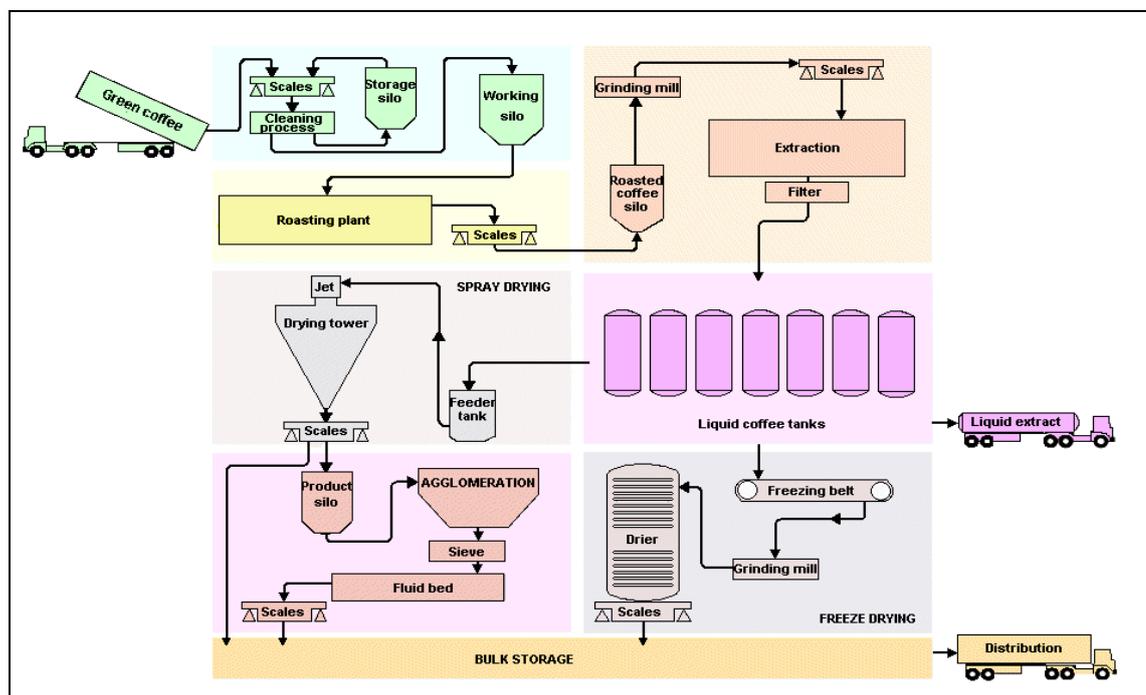


Figure 2.21: Instant coffee manufacturing

The arriving green coffee is picked up by discharge hoppers and mechanically cleaned through sifting and air separation before it reaches the silos. The raw coffee is roasted to enable its characteristic aromas and flavours to be appreciated. Then, after the coffee beans are ground, hot water is added to produce an extract. The extract is clarified and concentrated. A portion leaves the company in its now liquid form. This portion is transported by a road tanker to other installations for further processing.

The separation of the extract from water can be carried out by means of spray drying or freeze drying. Spray drying is carried out in a 30 metres high tower. The liquid coffee extract produced during the extraction is injected at the top, the drops fall downwards and reach a hot zone in which the water is extracted. On the floor, the dry, now powdered form of the product, is drawn off. The heat utilised can be partially recovered through countercurrent heat-exchangers. Also, the water used in the extraction process can be collected after drying to be re-used during production.

After drying, a portion of the end-product is transported for pelletising/agglomeration. With the aid of agglomeration processes, the fine grained powder particles that are created during drying combine into coarser particles. The particles are moistened through the addition of steam and water and conglomerated on rotating surfaces or belts. During this process, the residual moisture of the products is raised again, so subsequent drying in vibration driers is necessary.

During freeze drying, the extract is first frozen and reduced in size. In the subsequent drying step, the moisture is extracted under a high vacuum. For the freezing of the extract, extremely low temperatures, e.g.  $<-50\text{ }^{\circ}\text{C}$ , are required. In the example installation, the cold temperature is produced by ammonia adsorption refrigeration plants, so the use of chlorofluorocarbons can be avoided. The removal of the ice is carried out under vacuum. The vapour is evacuated from the drying chamber by means of special high performance vacuum pumps. The exhaust air resulting from this, as well as containing volatile coffee ingredients, also contains quantities of oil from the pump system. The oil mists are intercepted in oil filters, and the separated oil content is recirculated. This process results in a granular final product.

Finally, the dried instant products are filled into bulk packaging, e.g. aluminium containers and big bags, of approximately 350 – 400 kg and prepared for shipping.

### **2.2.13.3 Decaffeinated coffee**

Green beans are moisturised by steam or water to a moisture content of around 20 %. Solvents are then used to extract the caffeine from the wet beans. Decaffeination of coffee is carried out by extraction with decaffeinating agents, such as water or another solvent such as methylene chloride, coffee oils, ethyl acetate or supercritical  $\text{CO}_2$ . Extraction yields of 97 % of the caffeine can be obtained. Steaming or stripping is used to remove solvent from the beans. Two main extraction methods for decaffeination can be distinguished, i.e. the direct and indirect methods. The beans are then re-dried to their original moisture content prior to roasting. Solvent extraction of the caffeine, from the extract used to make instant coffee rather than from the bean itself, may also be applied.

The direct method is called solvent decaffeination. In this method, solvents, such as methylene chloride, coffee oils, ethyl acetate or supercritical  $\text{CO}_2$ , are used. The main process parameters are temperature and time. These vary depending on the type of coffee and on the type of solvent. For example, when coffee oil is used as the decaffeinating agent the process may take 6 to 9 hours at  $95\text{ to }105\text{ }^{\circ}\text{C}$ , whereas supercritical  $\text{CO}_2$  is used under high pressure at  $40\text{ to }80\text{ }^{\circ}\text{C}$  for 5 to 30 hours. Table 2.8 summarises the process.

|   | <b>Action</b>                                     | <b>Effect</b>   |
|---|---|---|
| 1 | Green beans are first soaked with water and steam | Beans swell by 30 – 40 %  |
| 2 | A decaffeinating agent is added to the wet beans  | The agent solubilises the caffeine from the beans                     |
| 3 | The agent is drained or steamed away              | The agent, together with 97 % of caffeine, are removed from the beans |
| 4 | The beans are dried by hot air or vacuum drying   | The beans are dried and are now ready for roasting                    |

**Table 2.8: Solvent decaffeination process**

The indirect method is called water decaffeination. In this method, water is used as the extraction solvent. The process is described in Table 2.9.

|   | <b>Action</b>   | <b>Effect</b>  |
|---|---|--|
| 1 | Green beans are first soaked with water and steam   | The water extracts the caffeine, but also some soluble coffee solids   |
| 2 | The beans are separated from the aqueous solution   | The water extract containing caffeine and coffee solids is separated   |
| 3 | Water extract is passed over an activated charcoal bed. A solvent, e.g. methylene chloride, may be used instead of activated carbon | The caffeine is removed from the solution by activated carbon filtration or methylene chloride. The coffee solids remain in the aqueous solution |
| 4 | The decaffeinated extract is concentrated and added back to the pre-dried decaffeinated beans                                       | Beans and coffee solids, now without the caffeine, are ready for roasting  |

**Table 2.9: Water decaffeination process**

### 2.2.14 Yeast

Yeasts are single cell fungi used in a wide range of fermentation processes such as baking, beer brewing and the manufacture of wines and spirits. Yeast is usually supplied to food manufacturers either in a crumbled/compressed form or as active dry yeast. Although methods vary, the essential steps in conventional processing are as described below.

Propagation takes approximately 6 to 8 days on a commercial scale using propagators sized between 91000 and 227000 litres. Yeast production initially involves a series of small propagations. The yeast produced at each stage being used to seed the subsequent propagation. Ingredients typically added to the fermenter are cane and beet molasses, blended and clarified before addition; ammonia; phosphoric acid; vitamins; minerals and de-foaming agents. Aeration of the fermenter is essential to achieve optimum growth. Air is introduced by bubbling through a series of parallel pipes fitted at the bottom of the vessel. In agitated vessels, air is usually introduced through a doughnut shaped sparger, located just underneath the stirred blades. In general, 100 grams of dry yeast matter require 102.5 grams of oxygen to be supplied during fermentation. Temperature and acidity must be regulated to optimise yields. Typically, fermentation is carried out at 30 °C and at a pH of 4.5 – 6.5. Water may be used in external heat-exchangers or internal coils to maintain the fermentation temperature, which otherwise tends to rise due to the yeast growth.

After propagation, the fermenter contents are cooled and the yeast crop is removed by centrifugal separators. The yeast cream is washed to improve its colour and cooled. Crumbled yeast is produced by pressing in a plate and frame filter or a vacuum filter. Alternatively the crumbled yeast may be mixed with emulsifiers and extruded to produce yeast blocks. Dried yeast is produced in a similar manner but is extruded through a perforated plate to produce strands of around 3 mm diameter and 0.3 to 1 cm long. The strips are usually dried in rotary or tunnel driers before grinding and packaging. Dried yeast is usually packed in hermetically sealed containers or film with a headspace of nitrogen to extend its active shelf-life.

### 2.2.15 Malting

Malt is a product derived from germinated grain, e.g. barley, oats or wheat, which is dried in kilns. Malts are fermented to make beers and lagers or may be fermented and then distilled to make spirits such as whisky. Malts may also be used in a range of foods such as non-alcoholic malted drinks, breakfast cereals, baby foods and animal feeds.

Malting activates and develops a number of enzymes including amylolytic and proteolytic enzymes. Amylolytic enzymes break down starch to fermentable carbohydrates. Proteolytic enzymes act as flavour precursors and as nutrients for yeast in subsequent fermentations. Malting involves controlled wetting by steeping, germination and drying of the grain. The process must be carefully controlled to induce the desired physico-chemical changes required, whilst at the same time minimising weight loss due to germination and respiration. The malted grain is dried to halt growth, stop enzymic activity and produce a stable product with the desired colour and flavour. Drying is followed by cooling down to 25 to 35 °C and by the removal of malt sprouts.

Two types of malt are generally produced on a commercial scale, i.e. brewers' and distillers' malts. Both types use barley as the starting raw material. Other cereals, such as wheat or rye, can also be used. Brewers' malt is made from plumper, heavier barley kernels with a friable starch mass. The barley is cleaned and then steeped in water at around 16 °C ranging from 10 to 25 °C for about 1 to 3 days. The actual temperature and steeping periods depend on the equipment, the process parameters, the raw material and the finished malt to be obtained. Steeping may occur in alternate stages of wet and dry periods. The barley is germinated at moisture contents of about 45 %, ranging from 30 to 50 %, depending on the same issues.

The resulting green malt is air-dried in kilns. Hot air, is blown through a layer of green malt of about 50 to 150 cm thickness, without any fluidisation of the batch. The blowing lasts around 16 to 24 hours in one floor kilns and 32 to 48 hours in two floor kilns. For pale coloured malts, resulting in a moisture content of 3 to 6.5 %, the starting air temperature is around 50 °C and it is increased to around 70 to 85 °C. To obtain darker coloured malts, with lower humidity levels, the temperature is increased further to 130 °C. Kilning is carried out in several stages to ensure that moisture is removed effectively without unduly reducing the enzymatic activity. In general, the airflowrate reduces and the air temperature increases as the kilning progresses. At the end of the kilning process, the dried malt is cooled down to about 25 to 35 °C and the malt culms are removed.

Distillers' malt, also called high diastatic malt, is made from small kernelled barley which is high in protein and enzymic potential. The barley is steeped at higher moistures levels ranging from 45 to 49 % and dried at lower temperatures, ranging from 49 to 60 °C to a higher final moisture content ranging from 5 to 7 %. Brewers' malt tends to be darker than distillers' malt and has an increased flavour and aroma.

Germination of the steeped grain can be brought about with a range of equipment, but essentially the process consists of subjecting the grain to a stream of humidified air at around 10 – 30 °C, depending on the equipment, the process parameters, the raw material and the finished malt to be obtained. The grain temperature varies between 15 and 45 °C due to the heat developed from respiration. Periodically, the grain is slowly turned and, in some cases, humidified to ensure an even temperature distribution and to prevent matting of rootlets. Germination has traditionally been carried out on concrete floors in cool moist rooms with the grain turned manually, but this method is now being replaced by more modern mechanised techniques.

After kilning, malt sprouts are removed in a cleaning stage to yield the final malted grain. This grain may be milled to produce malt flour. Malt extract is produced by hot water extraction from the finished malt, as carried out in the first stage of the brewing process, and then by concentrating the resultant extract, by means of the evaporation of water in evaporation vessels. The raw grain, the green malt or the finished malt can further be processed in the roasting drum to produce roasted barley, caramel malt or roasted malt of different colours and flavours.

### 2.2.16 Brewing

Beer is traditionally considered to include products such as lager, e.g. Pilsner malt and Munich malt, ale, porter and stout. It is an alcoholic drink derived from malted barley, with or without other unmalted cereal grains, and flavoured with hops. Sugar may also be added. There are three basic steps in the process; mashing, fermentation, and maturation/conditioning.

### 2.2.16.1 Mashing

Grains are normally received in bulk at breweries and transferred to silos. The malted barley is milled before use, the aim is to crush the endosperm with minimal damage to the husk. After milling, the ground materials or grist are mashed to produce a fermentable substrate for yeast fermentation. Additives may be used as a supplementary carbohydrate source, either to the mash kettle, e.g. maize grist or rice, or to the wort kettle, e.g. sucrose or glucose/maltose syrup. The grist is mixed with hot water to produce a thick slurry. The mix is then held for a sufficient period to allow the enzymes present in the malted barley to break down starch and proteins in the cereals.

Depending on the way in which the temperature is raised, mashing processes are classified into two types, i.e. infusion or decoction mashing. With infusion mashing, the entire mash is heated up, with appropriate rests until reaching the final mashing-off temperature. In decoction mashing, the temperature is increased by removing and boiling part of the mash. By returning it back to the remainder, the temperature of the total mash is increased to the next higher rest temperature. The vessel used for mashing is known as a mash tun. The wort is separated from the brewers grain by filtration in a mash filter or by straining. This is called lautering and takes place in lauter tuns. Once the so-called first wort has run off, the water is sprayed over the spent grist to extract as much wort as possible. After completion of the lautering, the leached brewers grains are discharged to silos and traditionally sold to farmers for use as cattle feed.

### 2.2.16.2 Fermentation

The wort is boiled for for 1 to 1.5 hours in the wort kettle with hops or hop extracts, releasing bitter substances that are dissolved. The wort is boiled with a boiling intensity of 5 to 8 % evaporation of casting volume per hour. A coarse coagulum of proteinaceous precipitated material is separated from the wort. This is known as the hot trub. Synthetic additives, based on polyester, result in a compact separation of the unpleasant, coarse, and bitter-tasting hot trub.

The wort is clarified in a whirlpool to remove the hops and then cooled to the pitching temperature. The hot cooling water, of about 75 to 85 °C, is collected and used as brewing water and for cleaning. It is possible to produce stronger wort than that corresponding to the original gravity of the final beer produced and it is possible later, before or after fermentation, to dilute it with water to the desired extract content. This is called high gravity brewing. Whether dilution is performed before or after fermentation depends, among other things, on local legislation. A further aim of wort boiling is the inactivation of all enzymes, sterilisation as well as concentration of the wort.

The clear hopped wort is aerated to encourage yeast propagation prior to fermentation and yeasts are added. The particular yeasts strains used are typical for beer production. Yeasts are divided into two major groups, i.e. top and bottom fermenting yeasts. Yeasts that tend to rise to the top of the fermentation vessel are typically used for ales and have a fermentation temperature of about 15 to 25 °C. Yeasts which tend to settle to the bottom of the vessel toward the end of fermentation are typically used in lagers, where the fermentation is normally performed at 8 to 15 °C. To maintain the desired fermentation temperature, the tanks are cooled. At the end of fermentation, the yeast is separated from the product. A part of it is used for another batch, and the remainder is disposed of or considered to be a co-product.

### 2.2.16.3 Maturation/conditioning

Lagers require conditioning by chilled storage for several weeks before clarification. The beer is generally clarified in a diatomaceous earth filter, e.g. kieselguhr. After carbonation, the beer may be subjected to a number of preservation processes, such as flash pasteurisation and aseptic filling, membrane separation or in-container pasteurisation.

Before bottling, the beer is filtered through a filter cake. Proven materials for this purpose are mud-free kieselguhr; calcined and screened diatomaceous earth of various particle size distribution; and perlite from ground and calcined glassy rock of volcanic origin. Activated carbon may be used to correct a mild off-taste. For example, it is usually used in the treatment of rest beers. Shortly before filtration, hydro- and xero-silica gels may be added to contribute to the build-up of the filter cake. Fining, by the addition of, e.g. cross-linked polyvinylpyrrolidone (PVP) and polyvinylpolypyrrolidone (PVPP) is carried out to clarify the beer and, e.g. reduce the polyphenol concentration.

Cleaning agents and disinfectants are also used.

### 2.2.17 Distilling

The use of distillation in the FDM sector can be illustrated by the following two examples; the distillations of Scotch whisky and cognac.

#### 2.2.17.1 Scotch whisky

Distillation units in the production of scotch whisky range from simple pot stills to continuous multicolumn stills. Energy is introduced in the form of steam to the bottom of the still and selectively volatilises the alcohol and other components from the fermented liquids and pre-distilled alcohol/water mixtures. The volatile components are recirculated within the still to achieve the correct separation, selection and concentration of alcoholic/aqueous compounds for the many varied and desirable congener profiles required by the various types and brands of products. Stills can be operated singly or in series. The volatile components are condensed by heat-exchange with water in condensers and removed as a liquid spirit. The residual material known as pot ale, spent lees, stillage or spent wash, is discharged from the bottom of the still. In column stills other fractions are also removed such as fusel oils and high feints. The high feints are fed back into the stills and the fusel oils, which are mainly amyl alcohol, are sold as a co-product.

#### 2.2.17.2 Cognac

Cognac is obtained by the distillation of white wines harvested in the controlled appellation area. The distillation of Cognac is a two-stage process. In the first stage, a first distillate, known as “brouillis” is obtained. This has an alcoholic strength of between 28 to 32 % volume. In the second stage, the brouillis is returned to the boiler for a second heating, known as “la bonne chauffe”. The distillation heads, secondes and tails are separated, leaving only the heart of the spirit. There is a restriction on the maximum strength of distillation, which must not exceed 72 vol-% alcohol. The time of each stage is about 12 hours.

Distillation is carried out in two separate heatings or chauffes in a special Charentais copper pot still comprising a characteristically shaped boiler, heated with a naked flame and topped with a cowl shaped like a turban, an olive or an onion. A Charentais still often has an energy saving wine reheater. This device, in which the heat is provided by the alcohol vapours passing through it, preheats the wine, which is to be distilled in the next cycle. The final day for distillation is 31 March of the year following harvesting.

Maturation must be carried out in Limousin or Tronçais oak casks. As with other brandies and matured wine spirits, maturation was aided by the use of oak extracts, but this practice is becoming less common in Cognac. French regulations prohibit the use of additives in the final product, other than water and sugar or caramel, and restrict the minimum strength to 40 vol-% alcohol.

## 2.2.18 Wine

This section includes red and white wine manufacturing [134, AWARENET, 2002].

### 2.2.18.1 Reception

When grapes are received at the winery, they are sorted by variety, quality and quantity. Containers are emptied directly into either crushing or transport equipment. Emptied containers are cleaned. The cleaning water is drained.

### 2.2.18.2 Grape crushing and destemming

Grape crushing or mashing takes place in grape mills. If maceration is intended, the mash can be stored in mash containers. To prevent the mash from oxidation  $H_2SO_3$  is added. The decision as to whether destemming of the white grapes is necessary before the grape mash is made depends on the variety and ripeness of the grapes as well as on the further processing of the mash.

### 2.2.18.3 Pressing

For white wine, the mash is transported to the wine press. The resulting unfermented grape juice is referred to as must. Sulphur dioxide is often added at this stage at the rate of 100 – 150 mg/l to suppress undesirable micro-organisms, e.g. grape skins are often covered with bacteria and moulds, as well as the yeasts used in the process. The solid residues, e.g. pomace and marc, are then separated.

For red wine, when the fermentation process is finished, i.e. when the sugar levels are under 0.1 %, the wine is taken from the bottom of the tank and the marcs are transferred to the wine press to extract the remaining wine.

### 2.2.18.4 Fining

The fining agents used in winemaking are gelatine, casein, isinglass, chitin, albumin or egg white; natural mineral adsorbents, e.g. bentonite, diatomaceous earth or silica; and synthetic polymers, e.g. PVPP. It is reported that sediments from clarification are separated by centrifugation or filtration. This removes unwanted particles left in suspension.

### 2.2.18.5 Fermentation

Alcoholic fermentation takes place in large stainless steel fermentation reactors or vats with or without the addition of pre-cultivated yeast, e.g. usually *Saccharomyces cerevisiae*, and under rigorous temperature control. White wine is fermented after marc separation, while red wine is fermented together with grape marcs. Red wine, and sometimes white wine as well, goes through a second malolactic fermentation. This is a bacterial fermentation that converts the malic acid into lactic acid.

### 2.2.18.6 Ageing

After fermentation, wine is cooled to 4 – 5 °C and transferred to barrels or wooden vats made of oak for ageing. This allows the wine to stabilise and to develop softer tannins and complex flavours. Lees are separated from the wine every 3 to 4 months. The barrels are then washed and refilled.

### 2.2.18.7 Cold stabilisation

Cold stabilisation involves rapid cooling of the wine to near freezing temperatures to precipitate tartrate crystals which are undesirable in the bottled wine, whether present in the cork or in the bottom of the bottle. Tartrate precipitates in the tanks and is removed with an alkaline cleaning solution of 10 % caustic soda.

### 2.2.18.8 Bottling

Before bottling, wine is passed through a filtration system to remove remaining solid and insoluble turbid compounds. Bottling involves the microbial stabilisation of the wine and preserves the wine from important changes in taste and chemical composition.

### 2.2.19 Soft drinks

Soft drinks can be categorised into two main types, i.e. carbonated and still. Soft drinks include spring waters, fruit and juice based drinks such as cordials, squashes and barley waters; flavoured drinks such as ginger beer; tonic waters and lemonades, as well as infusions such as tea and coffee.

Ingredients typically found in most soft drinks include water, sweetener, acid and flavourings. Optional ingredients include fruit, carbon dioxide, preservatives and colour. Water is the main ingredient of all soft drinks and, as such, the quality of the water, in terms of its microbiological loading and other parameters which affect the final sensory qualities of the drink, are of paramount importance. Most soft drinks are sweetened with natural sweeteners such as sugar and sugar syrups, and/or intense sweeteners such as saccharin and aspartame. Flavourings used in manufacture are often derived from highly concentrated liquid mixtures of plant extracts such as fruit, flowers, seeds, leaves, bark and root. Alternatively, they may be synthetic.

All sparkling soft drinks require the addition of carbon dioxide. This may be sourced as a co-product from the petroleum, beer and whisky industries, or produced on site. The preservation of soft drinks can be achieved by a number of techniques including heating, chemical preservation and filtration. These methods, in combination with low pH, prevent microbiological spoilage.

The basic processes for the manufacture of soft drinks involve the mixing of ingredients in the syrup room, followed by the addition of water that has been subjected to various water treatments. The mixture may be heat processed or chemically preserved at this stage. The product is carbonated if required. Alternatively, after the syrup and water are combined, the product may be filled into packaging and in-pack heat processed. Syrups may require filtration or homogenisation and may be pasteurised. Most packaging is cleaned prior to filling, either by rinsing with water, possibly containing rinsing aids, or by air blasting.

### 2.2.20 Citric acid

Citric acid, a tricarboxylic acid, exists widely in nature and is produced in almost all living cells as an intermediate substance in the metabolic cycle. Most plant and animal tissues, as well as human serum, contain citric acid in a significant quantity.

The most economical method to produce citric acid is fermentation, which employs a strain of *Aspergillus niger* as an inoculum, to convert sugar to citric acid. The fermentation feedstock or substrate is a carbohydrate, usually molasses, crystalline sugar, glucose from wheat, maize or potato starch, or isomerase. There are two types of fermentation processes, i.e. submerged and surface fermentation. Submerged fermentation is preferred to surface fermentation.

Submerged fermentation consists of three main phases, i.e. fermentation, recovery, and purification of citric acid. The flowchart for this process is presented in Figure 2.22.

In citric acid fermentation, the substrate is prepared in a tank and then sterilised. The inoculum is produced under controlled aseptic conditions. The inoculum and the substrate are transferred aseptically to the production fermenter. The fermentation process requires 3 to 14 days. Finally, the biological solids called mycelium are removed by filtration.

In the recovery of citric acid, the dissolved citric acid is separated from residual sugars, proteins and other soluble impurities by the addition of lime precipitating calcium citrate. Then, the slurry containing calcium citrate is filtered. The filtrate is washed to remove soluble impurities. The waste water generated is discharged. Sulphuric acid is added and this converts the calcium citrate to calcium sulphate and citric acid. Finally, the precipitated calcium sulphate or gypsum is filtered from the slurry and the remaining citric acid solution is further treated.

Ultimately, the citric acid solution is purified by ion exchange and carbon adsorption. The citric acid solution is evaporated and crystallised from the solution (first crystallisation). The citric acid crystals are centrifuged. Later, citric acid is dissolved in water and crystallised again from the solution (second crystallisation). The crystals are centrifuged yet again and are dried, milled and sieved. The resultant citric acid is then packaged.

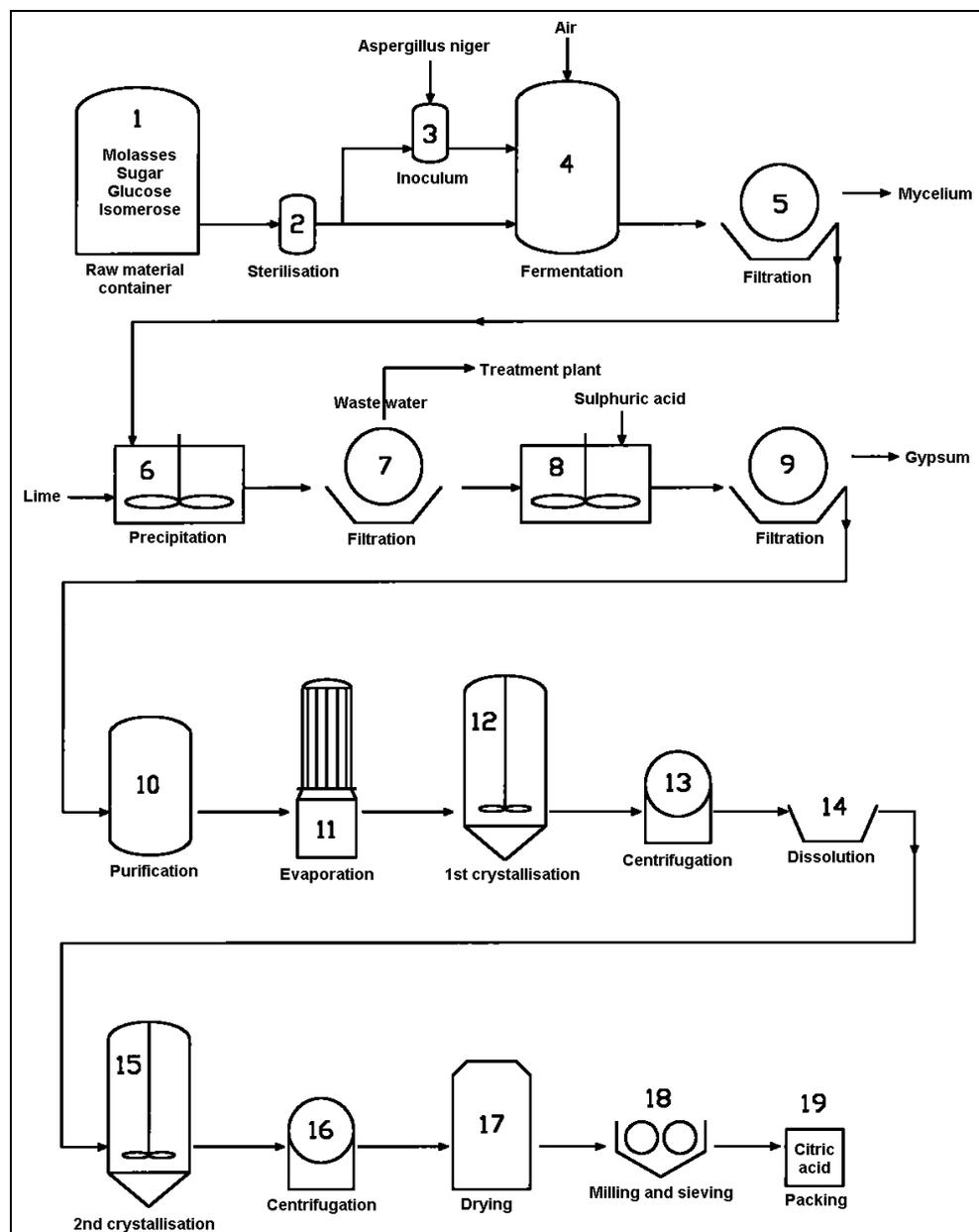


Figure 2.22: Citric acid fermentation process  
[151, Austrian contribution, 2002]

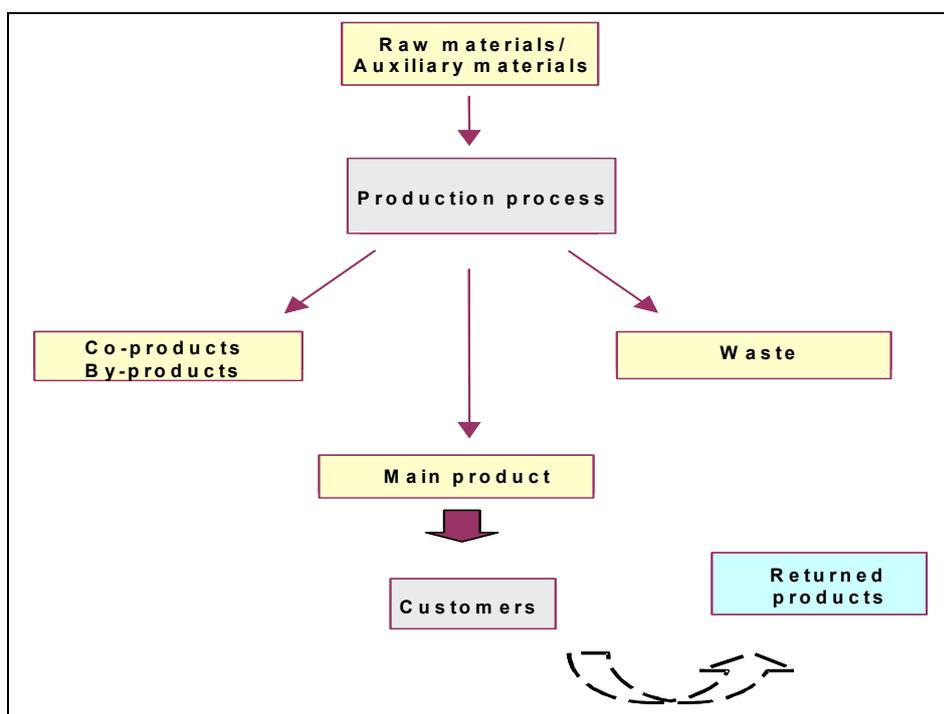


### 3 CURRENT consumption AND emission levels

This chapter presents the data and information provided about current consumption and emission levels in the FDM sector. Section 3.1 gives general information about consumption and emission levels in the whole sector. Section 3.2 gives more detailed information about the processing techniques and unit operations listed in Table 2.1. Section 3.3 reports data for specific FDM sectors.

In the FDM sector, energy, water and chemicals are consumed and gaseous, solid and liquid outputs are generated. These may have a negative impact on the environment and may be due to the inefficient use of materials or processes.

This chapter also contains information about outputs that are not the main final product and are not disposed of as waste. The FDM sector distinguishes between main products, co-products, by-products, returned products and waste, as shown in Figure 3.1. Normally the main product has the highest economic value.



**Figure 3.1: Output stream terminology used in the FDM sector**  
[1, CIAA, 2002]

In this document, co-products, by-products and returned products have the following meanings.

A co-product is a material, intentionally and unavoidably, created in the same process and at the same time as the main product. Both a main product and a co-product may each meet a set specification or design, and individually each is capable of being used directly for a particular purpose. For example, in the FDM sector some co-products are wheat gluten, maize gluten feed, maize gluten meal, maize germ, wheat feed, corn steep liquor, fruit pulp, concentrated fruit water, potato fibres, potato proteins, potato fruit water, malt culms, small barley and husks.

A by-product is a residual material which arises during the manufacture of a product. It may be used directly itself as an effective substitute for a product or may be used as an ingredient in another manufacturing process to create a different product, e.g. sludge and filter residues from filtration.

Returned products are those returned from retailers and wholesalers because they do not meet the required specification or because their shelf-life has expired.

The consumption and emissions information is important as part of the benchmarking process, and in the selection of techniques considered to be BAT.

Benchmarking is a technique used to assess performance against either internal or industry standards [11, Environment Agency of England and Wales, 2000]. Operational or technological improvement measures first applied at one site, may be applicable at others, even in different FDM sectors. These techniques may be considered in addition to comparing numerical consumption and emission levels.

Typically, benchmarks are expressed as ratios, but can be expressed as percentages, e.g. of efficiency. In this respect, data on waste minimisation, water and energy consumption, odour, noise and emissions to air and waste water, are generally relevant. Table 3.1 shows quantitative benchmarking parameters applicable in the FDM sector.

| Performance monitor    | Measurement   |
|------------------------|---|
| Air emissions          | Mass of emission per unit of production or per unit of raw material                                 |
| Waste water            | Volume of water, mass of contaminants or BOD/COD per unit of production or per unit of raw material |
| Solid waste            | Mass of waste per unit of production or per unit of raw material                                    |
| Energy resources       | Energy use per unit of production or per unit of raw material                                       |
| Utilities and services | Use of water, compressed air or steam per unit of production or per unit of raw material            |
| Other                  | Consumption of specific materials, e.g. packaging, per unit of production                           |

**Table 3.1: Quantitative benchmarking parameters applicable in the FDM sector [11, Environment Agency of England and Wales, 2000]**

Data on water and energy consumptions vary, not only with the type of process and how it is operated, but also with the size of operation.

Data on emissions to air and water are available for some sectors and even for some processes within installations, but the latter are scarce. In the future, more detailed information may be available about emissions to air and water, when this is reported to the EC's European Pollutant Emission Register (EPER). This is a requirement under Commission Decision 2000/479/EC [221, EC, 2000]. Guidance from the EC [93, EC, 2000] includes an FDM sector-specific checklist for the pollutants likely to be emitted to air and water. For FDM activities under Annex I paragraph 6.4 of the IPPC Directive, six air pollutants, i.e. methane, carbon monoxide, carbon dioxide, HFCs, ammonia and NO<sub>x</sub>, and four water pollutants, i.e. total nitrogen, total phosphorus, TOC and chlorides, are listed.

Within the FDM sector, the most common benchmarks compare utilities' consumption against production and, therefore, give a good indication of the efficiency and also of wastage occurring within the process. This is also called quantitative benchmarking. The percentage of raw materials going to the final main products is variable and waste minimisation is generally considered as a cost effective goal for all manufacturers but benchmarks are not readily available. Table 3.2 shows some examples of the percentages of raw materials which end up in the final main product.

| Production process  | % of raw material in the main final product |
|---|---|
| Fish canning  | 35 – 70                                     |
| Fish filleting, curing, salting and smoking   | 25 – 50                                     |
| Crustacean processing   | 40 – 50                                     |
| Mollusc processing  | 50 – 80                                     |
| Milk, butter and cream production   | ~99   |
| Yoghurt production  | 94 – 98                                     |
| Fresh, soft and cooked cheese production  | 10 – 15                                     |
| White wine production   | 70 – 80                                     |
| Red wine production   | 70 – 80                                     |
| Fruit and vegetable juice production  | 50 – 70                                     |
| Fruit and vegetable processing and preservation   | 70 – 95                                     |
| Vegetable oils and fats production, i.e. crude vegetable oil, protein rich meal, lecithin and fatty acids from oilseeds | 30 – 60                                     |
| Maize starch production   | 62.5  |
| Maize starch production (including animal feed)   | 99  |
| Potato starch production  | 20  |
| Potato starch production (including animal feed)  | 30 – 35                                     |
| Wheat starch production   | 50  |
| Wheat starch production (including animal feed)   | 99  |
| Food and animal feed production from sugar beet   | 25 – 50                                     |

**Table 3.2: Percentage of raw materials which end up in the final product in some processes [134, AWARENET, 2002]**

## 3.1 General consumption and emission information

### 3.1.1 Water

#### 3.1.1.1 Water consumption

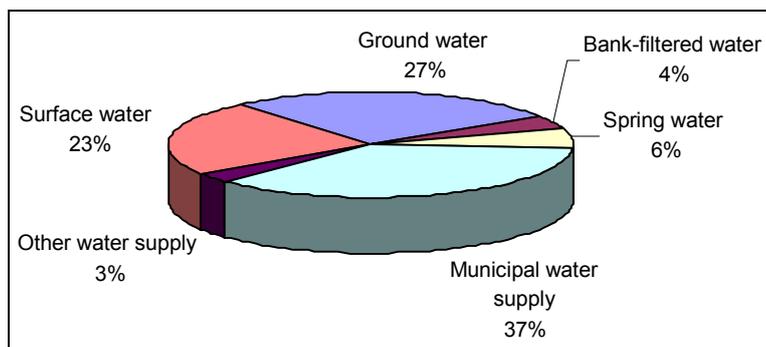
Water consumption is one of the key environmental issues for the FDM sector. Water has many different uses, e.g:

- for cooling and cleaning
- as a raw material, especially for the drinks industry
- as process water, e.g. for washing raw materials, intermediates and products
- for cooking, dissolving and for transportation
- as auxiliary water, e.g. for the production of vapour and vacuum
- as sanitary water.

The quality of water needed depends on the specific use.

In 1998 in Germany, the total industrial water consumption was 8500 million m<sup>3</sup> of which 304 million m<sup>3</sup> was used by the FDM sector. Nevertheless, the actual amount of water used in the FDM sector in that period was reported to be 1730 million m<sup>3</sup>, i.e. more than the total consumption figure. This is because of the proportion of water that was recycled and re-used. On average, the number of times water was re-used in the German FDM sector increased from 3.4 times to 4.2 times between 1995 and 1998.

Of the 1730 million m<sup>3</sup> of water used by the German FDM sector in 1998, 834 million m<sup>3</sup>, i.e. more than a half, was used as cooling water and 438 million m<sup>3</sup> was used as process water. The amount of water used from various sources by the German FDM sector in 1998 is shown in Figure 3.2.



**Figure 3.2: Water consumption by the German FDM industries in 1998 [182, Germany, 2003]**

In the FDM sector as a whole, about 66 % of the total fresh water used is of drinking water quality. In some sectors, like dairies, soft drinks and mineral water manufacturing and breweries, up to 98 % of the fresh water used is of drinking water quality.

### 3.1.1.2 Waste water

Although the FDM sector is an extremely diverse sector, certain sources of waste water are common to many of its sectors. These include:

- washing of the raw material
- steeping of raw material
- water used for transporting or fluming raw material or waste
- cleaning of installations, process lines, equipment and process areas
- cleaning of product containers
- blowdown from steam boilers
- once-through cooling water or bleed from closed-circuit cooling water systems
- backwash from regeneration of the WWTP
- freezer defrost water
- storm-water run-off.

#### 3.1.1.2.1 Quantity of waste water

The FDM sector has traditionally been a large user of water as an ingredient, cleaning agent, means of conveyance and feed to utility systems. Large FDM processing installations can use several hundred cubic metres of water a day. Most of the water not used as an ingredient, ultimately appears in the waste water stream.

Substantial reductions in the volume of waste water generated in this sector can be achieved through waste minimisation techniques (see, e.g. Section 4.1.7.6). There is no simple relationship between the amount of water used in cleaning and hygiene standards, and food safety legislation requirements prevent water use minimisation from causing unsatisfactory levels of cleanliness, hygiene or product quality.

Waste water flowrates may be very variable on a daily, weekly or seasonal basis. The waste water profile is largely dependent on production and cleaning patterns. In some sectors, e.g. sugar beet and olive oil production, processing takes place on a campaign basis and there is little or no waste water generated for part of the year.

### 3.1.1.2.2 Composition of waste water

FDM waste water is extremely variable in composition. It is, however, typically high in both COD and BOD. Levels can be 10 – 100 times higher than those of domestic waste water.

The BOD<sub>5</sub> content of the main FDM constituents and some products is shown in Table 3.3.

| BOD <sub>5</sub> content              |
|---------------------------------------|
| 0.65 kg/kg carbohydrate               |
| 0.89 kg/kg fat                        |
| 1.03 kg/kg protein                    |
| 0.07 – 0.10 kg/l milk                 |
| 0.18 – 0.37 kg/kg meat                |
| 0.06 – 0.09 kg/kg fruit or vegetables |

**Table 3.3: BOD<sub>5</sub> equivalent of general FDM constituents and some products**

The SS concentration varies from negligible to as high as 120000 mg/l. Waste water from, e.g. the meat and dairy sectors contain high concentrations of edible fats and oils.

Food processing waste waters vary from very acidic, i.e. pH 3.5, to very alkaline, i.e. pH 11. Factors affecting waste water pH include:

- the natural pH of the raw material
- pH adjustment of fluming water to prevent raw material deterioration
- use of caustic or acid solutions in processing operations
- use of caustic or acid solutions in cleaning operations
- acidic waste streams, e.g. acid whey
- acid-forming reactions in the waste water, e.g. high yeast content waste water, lactic and formic acids from degrading milk content
- nature of raw water source, either hard or soft.

Waste waters contain few compounds that individually have an adverse effect on WWTPs or receiving waters. Possible exceptions include:

- salt where large amounts are used, e.g. pickling and cheesemaking
- pesticide residues not readily degraded during treatment
- residues and by-products from the use of chemical disinfection techniques
- some cleaning products.

The presence of pathogenic organisms in the waste water may be an issue, particularly where meat or fish are being processed. The amount of plant nutrients may also be an issue. For the biological waste water treatment of the waste water, the ideal BOD:N:P ratio is about 100:5:1. At this level, FDM processing waste water would be too deficient in N and/or P to support biological activity during treatment. Excessive levels of P can also occur, particularly where large quantities of phosphoric acid are used in the process, e.g. vegetable oil de-gumming, or in cleaning. If such waste water becomes anaerobic during treatment then there is a risk that constituents containing phosphate could release phosphorus to the final discharge water. The use of nitric acid in the process produces a similar effect, thereby increasing the levels of nitrate in the waste water.

Some common sources of fugitive and unscheduled emissions, i.e. accidental releases, are:

- contaminated storm-waters
- storage tank leaks
- pipework leaks
- spillages
- bund drains
- leakages from flanges, pumps, seals and valve glands.

### 3.1.2 Air emissions

Air emissions can be divided into ducted, diffuse, and fugitive emissions. Only ducted emissions can be treated. Diffuse and fugitive emissions can, however, also be prevented and/or minimised [217, EC, 2003].

The sources of ducted emissions in the FDM sector are:

- process emissions, released through a vent pipe by the process equipment and inherent to the running of the installation, e.g. in frying, boiling, cooking operations
- waste gases from purge vents or preheating equipment, which are used only on start-up or shut-down operations
- emissions from vents from storage and handling operations, e.g. transfers, the loading and unloading of products, raw materials and intermediates
- flue-gases from units providing energy, such as process furnaces, steam boilers, combined heat and power units, gas turbines, gas engines
- waste gases from emission control equipment, such as filters, thermal oxidisers or adsorbers
- waste gases from solvent regeneration, e.g. in vegetable oil extraction installations
- discharges of safety relief devices, e.g. safety vents and safety valves
- exhaust of general ventilation systems
- exhaust of vents from captured diffuse and/or fugitive sources, e.g. diffuse sources installed within an enclosure or building.

The sources of diffuse emissions in the FDM sector are:

- process emissions by the process equipment and inherent to the running of the installation, released from a large surface or through openings
- working losses and breathing losses from storage equipment and during handling operations, e.g. filling of drums, trucks or containers
- emissions from flares
- secondary emissions, resulting from the handling or disposal of waste, e.g. volatile material from sewers, waste water handling facilities or cooling water.

The sources of fugitive emissions in the FDM sector are:

- odour losses during storage, filling and emptying of bulk tanks and silos
- stripping of malodorous compounds from a WWTP resulting in releases to air and/or odour problems
- storage tank vents
- pipework leaks
- fumigation
- vapour losses during storage, filling and emptying of bulk solvent tanks and drums, including hose decoupling
- burst discs and relief valve discharges
- leakages from flanges, pumps, seals and valve glands
- building losses from windows, doors, etc.
- settling ponds
- cooling towers and cooling ponds.

The main air pollutants from FDM processes, not including the pollutants released in associated activities such as energy production, are:

- dust
- VOCs and odour (some caused by VOCs)
- refrigerants containing ammonia and halogen
- products of combustion, such as CO<sub>2</sub>, NO<sub>x</sub> and SO<sub>2</sub>.

### 3.1.2.1 Odour

Odour is mostly a local problem. Some air emissions which are harmful may also be malodorous. For two identical installations producing the same products and using the same raw materials and process operations, one may be subject to considerable complaints whilst for the other, the odour emission may not be a problem. There are many cases where installations, previously situated in rural areas on the outskirts of a town or city, are now faced with odour problems as new housing estates have been constructed near the site as the town has grown.

In the vast majority of countries, odour emissions are regulated under the laws of nuisance. Some countries have quantified legislation. This quantified legislation can relate to either the magnitude of the malodorous emission or alternatively to a maximum concentration of a component or group of components which are known to cause malodorous emissions. The internationally accepted units of odour are “odour units per cubic metre” (OU/m<sup>3</sup>). Instrumental odour measurements exist but the quantification of odour is still based on olfactometry to a great extent.

In Germany, e.g. the legislation for malodorous processes is largely directed towards ensuring that the outlet concentration of organics is limited in relation to the process being conducted and the efficiency of the chosen abatement plan. The legislation, under TA Luft [82, BMU and German Federal Ministry for Environment Nature Conservation and Reactor Safety, 1986], contains a general statement about odour emissions and describes the need to consider containment, the surroundings and the ability of the abatement plan to achieve 99 % odour reduction for odour emissions greater than 100000 OU/m<sup>3</sup>. For specific process operations TA Luft provides maximum outlet concentrations of organics that should not be exceeded.

The Netherlands Emissions Guideline for Air [170, InfoMil, 2001], states that the national goal is the prevention or reduction of odour nuisance. It sets an upper limit of 5 OU/m<sup>3</sup> as 98 % for existing installations and suggests that a limit of 0.5 OU/m<sup>3</sup> as 99.5 % will have to be satisfied for new installations; the latter is not an upper limit.

### 3.1.3 Loss of materials

#### 3.1.3.1 Exceed weight/volume specification

Loss of products by overfilling occurs even with the most accurate filling equipment. Operating to average filling weight legislation, the packaged product will unavoidably contain marginally more than the nominal package contents. Because of its economic significance, overfill is normally very closely monitored by check-weighing on a continuous or sampling basis. Such loss of material is normally of no environmental significance. It is, however, very important when conducting a mass balance, to accurately quantify the amount of overfill, so that this can be allowed for in the mass balance equation.

#### 3.1.3.2 Spillage

Spillage of the product, e.g. onto the floor, results in the product being unfit for human consumption and must be defined as loss and waste, if not properly recovered. Routinely occurring spillage indicates poor equipment design, poor maintenance or poor operation, e.g. of a packaging line. This often causes a considerable loss of product and packaging material. When spillage occurs during manual handling, the working procedures may be at fault.

#### 3.1.3.3 Leakage/overflow

Leakage of liquid product from pipe joints and overflow from tanks may be an important source of loss of material and waste, if not properly recovered. These problems can be caused, e.g. by obsolete gaskets or faulty high level alarm switches.

### 3.1.3.4 Product defects/returned product

Products not meeting the required specification, whether identified prior to dispatch or returned by customers, can be a major source of loss of materials and waste, although some may be recovered. This group also includes over-produced fresh products, e.g. in cases where order fluctuations result in too much product being produced which cannot then all be sold in time due to shelf-life considerations.

### 3.1.3.5 Inherent loss

Some process equipment, even with the most appropriate technique, can cause a loss of materials and waste which is unavoidable by design. An example of inherent loss is the self-desludging centrifugal separator, where solids from the bowl, and inevitably some product, are flushed to waste during desludging.

A similar situation exists where the product is purged through the equipment with water at the end of production or at product change-over, e.g. in CIP systems. Inevitably the interface between the product and the water will not be sharp and depending on what measures are taken to minimise this, a greater or lesser quantity of a mixture of the two is produced.

### 3.1.3.6 Retained material

Retained material occurs when liquid products or ingredients cannot freely drain to the next stage in the process. This can, e.g. be caused by dips in supposedly continuously falling pipelines, which trap the product and prevent it from draining either way. Another example is where the product rises in the pipelines and any trapped product will then not drain away, thus leading to a loss of material. If the product cannot drain, then it must be purged with gas, water or a pigging system.

Also, with very viscous products, e.g. yoghurt, adhesion to the pipeline and tank walls is a significant source of retained material. Unless mechanically removed, e.g. by pigging, prolonged pre-rinsing is likely to be required.

### 3.1.3.7 Heat deposited waste

Whenever liquid products are heated, there is a likelihood of deposition of the product onto the heat-exchange surface. Deposits on the plates or tubes in heat-exchangers, and on batch kettles may not rinse off and when removed with detergents is lost in the waste water. In many sectors, these sources of loss are contained and recycled or recovered back into the process.

## 3.1.4 Energy

The FDM sector depends on energy for processing, storage, to maintain freshness and to ensure food safety. Process heating uses approximately 29 % of the total energy used in the FDM sector. Process cooling and refrigeration accounts for about 16 % of the total energy used.

In Germany, the FDM sector consumed about 54500 MWh/yr in 1998, representing 6.7 % of the total German energy consumption making it the fifth largest energy consumer among all industrial sectors. The energy was produced using 49 % gas, 23 % electricity, 21 % oil, and 7 % coal. The energy consumption doubled in 30 years from 1950 to 1980. There was a slight decrease in the 1980s and 1990s [2, Meyer, et al., 2000].

## 3.2 Consumption and emissions in unit operations

It is quite difficult to give quantitative data on the environmental aspects of individual processing techniques. This is due to a lack of reliable data or due to natural variations, e.g. seasonal, in many of the raw materials. This often leads to changes in the processing techniques applied. The ranges in the quantitative data are very largely due to the very wide variation in individual process applications. Often better quantitative information is available on the environmental aspects of the whole production line rather than on individual processing techniques, because measurements have not been made at unit operation level.

Examples are given of some qualitative and quantitative environmental aspects of typical production lines. In the description of environmental aspects of the various processing techniques, “solid output” covers both by-products from the process which could be valorised, as well as waste which cannot be valorised. For example, some by-products from the FDM sector can be used as animal feed.

The main sources of consumption and emissions are identified for each processing technique. The identified list of sources is not all encompassing, or every installation within an individual sector have every one of the emissions. The information is associated with the FDM sector as a whole. Local variations apply, depending on the raw materials used, the type of processes applied and how they are applied.

Some process emissions are considered to have little potential environmental significance and these are designated as minor, however, there could be specific installations where this designation may be incorrect. Such emissions must then be examined on a case-by-case basis.

The environmental impacts or process emissions for each of the unit operation described in Section 2.1 are summarised in Table 3.4. The symbols alongside each operation describe the characteristic of the emission. The meaning of the codes used are given in Table 3.5, Table 3.6 and Table 3.7.

| Code  | Unit operation  | Environmental impact |                    |        |
|---|---|----------------------|--------------------|--------|
|   |   | Air                  | Water              | Solid  |
| <b>A. Materials reception and preparation</b> |   |                      |                    |        |
| A.1   | Materials handling and storage  |                      |                    | W1     |
|   | Tank vents  | S1, S3               | N                  | N      |
|   | Silos   | S2                   | N                  | N      |
|   | Material handling/transport   | S1, S2, S3           | E1, E2, E3, E4, E5 | W1     |
| A.2   | Sorting/screening, grading, dehulling, destemming/destalking and trimming | S1, S2               | E1, E2             | W1, W3 |
| A.3   | Peeling   | N                    | E1, E2             | W1     |
| A.4   | Washing   | N                    | E1, E2             | W1     |
| A.5   | Thawing   | N                    | E1, E2             | W1     |
| <b>B. Size reduction, mixing, forming</b>     |   |                      |                    |        |
| B.1   | Cutting, slicing, chopping, mincing, pulping and pressing                 | N                    | E1, E2, E4         | W1, W2 |
| B.2   | Mixing/blending, homogenisation and conching                              | S1, S2, S3           | E1, E2, E4, E5     | W1     |
| B.3   | Grinding/milling and crushing   | S2, S3               | N                  | W1, W3 |
| B.4   | Forming/moulding and extruding  | N                    | E1, E2, E5         | W1     |
| <b>C. Separation techniques</b>               |   |                      |                    |        |
| C.1   | Extraction  | S1, S3               | E1, E2             | W1, W4 |
| C.2   | Deionisation  | N                    | E1, E3, E5         | W1     |
| C.3   | Fining  | N                    | E1, E2             | W1, W3 |
| C.4   | Centrifugation and sedimentation  | N                    | E1, E2             | W1, W3 |
| C.5   | Filtration  | M                    | E1, E2, E4         | W1, W3 |
| C.6   | Membrane separation   | N                    | E1, E2             | N      |
| C.7   | Crystallisation   | N                    | E1                 | N      |
| C.8   | Removal of free fatty acids by neutralisation                             | N                    | E1, E2, E3, E4     | N      |

|   |   |                       |                    |        |
|---|---|-----------------------|--------------------|--------|
| C.9                                     | Bleaching   | N                     | N                  | W1,W3  |
| C.10                                    | Deodorisation by stream stripping                         | S1, S3                | E1, E2, E4         | W2     |
| C.11                                    | Decolourisation   | N                     | E1,E2              | W1     |
| C.12                                    | Distillation  | S1, S3, S4            | E1,E2              | W1     |
| <b>D. Product processing technology</b> |   |                       |                    |        |
| D.1                                     | Soaking   | N                     | E1, E2             | W1     |
| D.2                                     | Dissolving  | N                     | E1, E2, E6         | N      |
| D.3                                     | Solubilisation/alkalising                                 | S1, S2, S3            | E1,E2              | N      |
| D.4                                     | Fermentation  | S1,S4                 | E1,E2              | W1     |
| D.5                                     | Coagulation   | N                     | E1, E2             | N      |
| D.6                                     | Germination   | S3                    | N                  | N      |
| D.7                                     | Brining/curing and pickling                               | N                     | E1, E2, E6         | W1     |
| D.8                                     | Smoking   | S1, S3                | E1                 | N      |
| D.9                                     | Hardening   | S1                    | E1, E2, E4         | W5     |
| D.10                                    | Sulphitation  | S6                    | N                  | N      |
| D.11                                    | Carbonatation   | S1, S4, S5,<br>S6, S7 | N                  | W3     |
| D.12                                    | Carbonation   | S4                    | N                  | N      |
| D.13                                    | Coating/spraying/enrobing/agglomeration/<br>encapsulation | S1                    | E1, E2, E4         | W1, W2 |
| D.14                                    | Ageing  | S1, S3                | E1,E2              | W1, W6 |
| <b>E. Heat processing</b>               |   |                       |                    |        |
| E.1                                     | Melting   | S1                    | E1, E2, E4         | W1, W2 |
| E.2                                     | Blanching   | S1                    | E1, E2, E6         | W1     |
| E.3                                     | Cooking and boiling                                       | S1, S3                | E1, E2, E4, E5, E6 | W1     |
| E.4                                     | Baking  | S1, S2, S3,<br>S4     | E1, E2, E4         | W1     |
| E.5                                     | Roasting  | S1, S2, S3,<br>S4, S5 | N                  | W1     |
| E.6                                     | Frying  | S1, S3                | E1, E2, E3, E4     | W1, W2 |
| E.7                                     | Tempering   | N                     | E1,E2              | N      |
| E.8                                     | Pasteurisation, sterilisation and UHT                     | N                     | E1, E2             | W1     |
| <b>F. Concentration by heat</b>         |   |                       |                    |        |
| F.1                                     | Evaporation (liquid to liquid)                            | S1, S2                | E1, E2, E5         | N      |
| F.2                                     | Drying (liquid to solid)                                  | S1, S2                | E1, E2             | W1     |
| F.3                                     | Dehydration (solid to solid)                              | S1, S2                | E1, E2             | W1     |
| <b>G. Processing by removal of heat</b> |   |                       |                    |        |
| G.1                                     | Cooling, chilling and cold stabilisation                  | S4                    | M                  | N      |
| G.2                                     | Freezing  | S4, S7                | N                  | N      |
|   | Cryoextraction  | N                     | E1                 | W1, W3 |
|   | Concentration by cold                                     | N                     | E1                 | N      |
| G.3                                     | Freeze-drying/lyophilisation                              | N                     | E2                 | N      |
| <b>H. Post processing operations</b>    |   |                       |                    |        |
| H.1                                     | Packing and filling                                       | S2                    | E1, E2             | W1, W6 |
| H.2                                     | Gas flushing and storage under gas                        | S4                    | N                  | N      |
| <b>U. Utility processes</b>             |   |                       |                    |        |
| U.1                                     | Cleaning and disinfection                                 | N                     | E1, E2, E3, E4, E5 | N      |
| U.2                                     | Energy generation and consumption                         | S2, S4, S5,<br>S6     | N                  | N      |
|   | Boiler blowdown   | N                     | E5                 | N      |
| U.3                                     | Water use   |                       |                    |        |
|   | Demineralisation plant                                    | N                     | E1, E2, E3, E5     | W1, W3 |
| U.4                                     | Vacuum generation   | S1                    | E1                 | N      |
| U.5                                     | Refrigeration   | S7                    | E5                 | N      |
| U.6                                     | Compressed air generation                                 | N                     | N                  | N      |

**Table 3.4: Environmental impacts of the FDM unit operations**  
[1, CIAA, 2002]

| Code  | Emissions to air |
|---|------------------|
| S1  | Odour            |
| S2  | Dust             |
| S3  | Organics*        |
| S4  | CO <sub>2</sub>  |
| S5  | NO <sub>2</sub>  |
| S6  | SO <sub>2</sub>  |
| S7  | NH <sub>3</sub>  |
| M   | Minor            |
| N   | None             |
| * Organics covers emissions containing organic material at the actual processing conditions and is regardless of the vapour pressure of the individual components present in the emission |                  |

**Table 3.5: Codes used for emissions to air**  
[1, CIAA, 2002]

| Code | Emissions to water                   |
|------|--------------------------------------|
| E1   | Soluble organic material (BOD/COD)   |
| E2   | Total suspended solids               |
| E3   | Acid/alkali                          |
| E4   | FOG                                  |
| E5   | Nitrate, nitrite, ammonia, phosphate |
| E6   | Dissolved solids                     |
| M    | Minor                                |
| N    | None                                 |

**Table 3.6: Codes used for emissions to water**  
[1, CIAA, 2002]

| Code | Solid outputs   |
|------|---|
| W1   | Organic, e.g. waste product/processing materials                  |
| W2   | Oils/fats/greases   |
| W3   | Inorganic, e.g. soil, calcium carbonate and bleaching earth       |
| W4   | Solvent   |
| W5   | Metals, e.g. nickel catalyst                                      |
| W6   | Packaging from process operations, e.g. paper, cardboard or drums |
| M    | Minor   |
| N    | None  |

**Table 3.7: Codes used for solid outputs**  
[1, CIAA, 2002]

### 3.2.1 Materials handling and storage (A.1)

#### 3.2.1.1 Water

The main release into water is caused by leakages. During the transport by water of solid raw materials, such as vegetables, roots and tubers, both organic and inorganic SS and soluble compounds are released to water. Cleaning of the various pipes and storage tanks also contributes to water usage and waste water load. The waste water may also contain acid/alkali solutions, FOG, nitrate, nitrite, ammonia and phosphate.

#### 3.2.1.2 Air emissions

Emissions to air can occur from vessel vents during filling, and/or conveying by air. These emissions may include dust, VOCs and odours, which are usually minor in quantity and local in effect.

### **3.2.1.3 Solid output**

Some solid residues can result from vessels or other material handling equipment and from packaging. They can be, e.g. re-used in the installation or elsewhere, sold as animal feed or may be disposed of as waste.

### **3.2.1.4 Energy**

Materials handling is almost exclusively electrically driven. No significant heat is involved. The environmental issues are minor and relate to electrical consumption.

### **3.2.1.5 Noise**

Short periods of noise may occur from certain types of vehicle-mounted blowers used to discharge solids and liquids from road vehicles into silos and other vessels.

### **3.2.1.6 Accidental release**

Accidental releases can occur, e.g. during unloading when connecting or disconnecting hoses and during storage if valves are not fully closed or maintained.

## **3.2.2 Sorting/screening, grading, dehulling, destemming/destalking and trimming (A.2)**

### **3.2.2.1 Water**

Wet screening may result in a waste water stream containing soluble organic matter and SS.

### **3.2.2.2 Air emissions**

When dry cleaning food/agricultural raw materials, dust may be produced. Odour may also be a problem. These emissions are minor in quantity and local in effect.

### **3.2.2.3 Solid output**

Material that is sorted out, or removed, is usually recovered as far as possible and then often used as animal feed. If the material cannot be used, it is disposed of as waste.

### **3.2.2.4 Energy**

Although sorting generally needs little energy, there are large variations in electrical energy consumption. For example, in vegetable processing, the sorting operation has an electrical energy consumption of 0 – 20 kWh<sub>e</sub>/t frozen vegetable. [32, Van Bael J., 1998]

### **3.2.3 Peeling (A.3)**

#### **3.2.3.1 Water**

In most peeling operations, a water spray is used to remove the peeled skin. Waste water is generated which contains SS. Conventional steam or hot water peeling uses large quantities of water, up to four times that required for caustic peeling, and produces waste water with high levels of product residue. At potato processing installations, the peels can contribute up to 80 % of the total BOD. In fruit processing, peeling waste water can account for as much as 10 % of the total waste water flow and 60 % of the BOD. Dry caustic peeling methods can greatly reduce the volume and strength of the waste water from this operation and allow for the collection of peel as a pumpable slurry. The use of caustic in peeling may lead to pH fluctuations in the waste water. Some produce, e.g. tomatoes, requires strong caustic solutions and the addition of wetting agents. Dry caustic peeling tends to have a lower caustic consumption than wet methods. In steam peeling, most of the peeled material is discharged with the steam; this results in the collection of a concentrated waste stream. Remaining traces are sprayed off with water. The process has a lower water consumption than other “wet” peeling methods.

#### **3.2.3.2 Air emissions**

When flame peeling is applied, some dust and odour emissions can occur.

#### **3.2.3.3 Solid output**

The peels are often recovered and used as animal feed, otherwise they are disposed of as waste.

Abrasion peeling has a significantly higher product loss than flash steam peeling, 25 % loss compared to 8 – 15 % loss, and considerably more waste water is produced. In caustic peeling, product loss is around 17 %. Dry caustic peeling reduces water consumption and produces a concentrated caustic paste for disposal.

#### **3.2.3.4 Energy**

Flash steam peeling, caustic peeling and flame peeling require heat; the other peeling operations use electrical energy.

#### **3.2.3.5 Noise**

Noise emissions may be a problem.

### **3.2.4 Washing (A.4) and thawing (A.5)**

#### **3.2.4.1 Water**

Water is required and the waste water typically contains dissolved organic matter, SS and salts.

#### **3.2.4.2 Solid output**

The dirt and vegetable matter removed during the washing of, e.g. sugar beets and potatoes, is sent for landspreading or for landfilling.

### 3.2.4.3 Energy

The electricity consumption for washing operations heavily depends on the vegetable concerned. Washing spinach, for instance, is energy intensive.

During washing operations, hot water can be used to increase the speed and efficiency of the washing. Most companies do not heat the water. Sometimes hot residual water from the blanching system is used for washing [32, Van Bael J., 1998]

Thawing using hot air consumes energy.

### 3.2.5 Cutting, slicing, chopping, mincing, pulping and pressing (B.1)

#### 3.2.5.1 Water

Waste water results mainly from the cleaning of equipment. It usually contains soluble organic material, such as small particles of meat, fruit and vegetables. In meat processing, the waste water may also contain soluble proteins, FOG and other solids, such as curing salts.

#### 3.2.5.2 Solid output

The by-products generated depend on the raw material and process, e.g. in meat cutting, typical by-products are bones, fat and skin. These are usually used for other manufacturing processes, which might even be outside the FDM sector, such as soap manufacture. Other typical outputs include fruit and vegetable peelings.

#### 3.2.5.3 Energy

Electrical energy is used for various equipment.

#### 3.2.5.4 Noise

Some high-speed, power-operated equipment is used which can generate high noise levels, e.g. circular saws used to cut through bones and bowl cutters. However, this is usually not an issue, as the noise typically does not carry to off-site receptors.

### 3.2.6 Mixing/blending, homogenisation and conching (B.2)

#### 3.2.6.1 Water

The use of water in this group of operations is normally restricted to cleaning the equipment. The amount used depends on the type of equipment. The resulting waste water contains soluble organic material, SS, FOG and may also contain nitrate, nitrite, ammonia and phosphate.

#### 3.2.6.2 Air emissions

In operations where solid and volatile materials are treated, emissions to air can occur. Odour may be produced by operations which involve VOCs. Dust is emitted in operations involving solids such as solid/solid mixing.

#### 3.2.6.3 Solid output

In operations where solid materials are processed, solid organic output may be generated when equipment is emptied for the next batch or for cleaning. Normally some losses occur during such operations. This solid waste can consist of raw materials or waste products. By careful operation and good housekeeping, the amount of solid output can often be reduced and any output resulting may be re-used or sold as animal feed.

#### **3.2.6.4 Energy**

These unit operations require mainly electrical energy input.

#### **3.2.6.5 Noise**

Homogenisation may be a source of noise.

### **3.2.7 Grinding/milling and crushing (B.3)**

#### **3.2.7.1 Water**

Wet grinding consumes large quantities of water.

#### **3.2.7.2 Air emissions**

Dust is emitted in operations involving solids. VOCs may also be emitted.

#### **3.2.7.3 Solid output**

Solid organic output is generated when equipment is emptied for the next batch or for cleaning. Some losses occur during such operations. This solid output can consist of raw materials or waste products and can be reprocessed or sold as animal feed.

#### **3.2.7.4 Energy**

Grinding requires a significant energy input.

#### **3.2.7.5 Noise**

Grinding is a source of noise.

### **3.2.8 Forming/moulding and extruding (B.4)**

#### **3.2.8.1 Water**

Waste water is generated during the cleaning of equipment and contains primarily soluble organic material and SS and may also contain nitrate, nitrite, ammonia and phosphate.

#### **3.2.8.2 Air emissions**

Extrusion at high temperatures may result in some air emissions of VOCs and odour.

#### **3.2.8.3 Solid output**

Some solid waste may be generated due to the loss of product at the beginning and end of the production process.

#### **3.2.8.4 Energy**

Typically, extruders are major users of electrical energy.

### **3.2.9 Extraction (C.1)**

#### **3.2.9.1 Water**

Water usage is an issue when water is used as a solvent in the extraction process. Also, extraction equipment is cleaned periodically to ensure efficient and optimum operating conditions. The frequency of cleaning depends on the product and extractor design. This cleaning will generate waste water containing soluble and insoluble organic material and SS.

For example, in the extraction process of oil from oilseeds with hexane, cooling water is needed in an amount of 0.2 to 14 m<sup>3</sup>/t oilseed. Furthermore, a certain amount of waste water is generated, mainly from the hexane/water separation, which amounts to 0.2 to 0.5 m<sup>3</sup>/t oilseed; the load being of 0.1 to 1 kg COD/t oilseed. The amounts of water consumption and of pollution depend on the cooling water system, e.g. once-through or with recycling, and on the kind of oilseeds. The throughput rate of the toaster also has a major influence on these parameters. Water consumption for the pressing of oil is minimal.

#### **3.2.9.2 Air emissions**

Extraction with organic volatile solvents may cause emissions of VOCs. Council Directive 1999/13/EC [157, EC, 1999] includes provision for oilseed extraction, including VOC emission limit values for vegetable oil and animal fat extraction, and vegetable oil refining activities.

Extraction plants may also cause odour, due to the emission of H<sub>2</sub>S and organic compounds. When extraction with water takes place, water vapour containing non-condensable VOCs may be released to the air.

#### **3.2.9.3 Solid output**

The solid output may be re-used as a product or co-product, or be disposed of. For example, after the removal of the adhering water, spent coffee grounds can be burned as fuel in steam boilers or used as raw material for further processing. The solid output may contain solvents.

#### **3.2.9.4 Energy**

Electrical energy and steam are required; the levels depend on the type of application. For example, energy consumption is of 170 – 390 kWh steam (600 to 1400 MJ) and 30 – 60 kWh<sub>e</sub>/t oilseed (100 to 200 MJ). The energy consumption depends mainly on the kind of oilseed and of the type of cooling water circuit.

#### **3.2.9.5 Noise**

Possible sources of noise are cooling towers, fans and steam safety valves.

### **3.2.10 Deionisation (C.2)**

#### **3.2.10.1 Water**

The regeneration of ion exchange columns produces water containing the chemicals used for regeneration, usually acids or alkalis and brine; ions removed from the product, minerals and impurities extracted from the used column. The pH of the waste water fluctuates. Regeneration starts with rinsing the ion exchange columns with water. This produces waste water containing soluble organic material and product residues, which depending upon their dilution, may be reprocessed.

### **3.2.10.2 Solid output**

The only solid output is the ion exchange resin at the end of its useful life. This can be anything from 6 months to 10 years depending on the operation and product, and the type of ion exchange resin used.

### **3.2.11 Fining (C.3)**

#### **3.2.11.1 Water**

Waste water is produced which contains soluble organic material and SS.

#### **3.2.11.2 Solid output**

Solid output is produced which contains organic and inorganic material.

### **3.2.12 Centrifugation and sedimentation (C.4)**

#### **3.2.12.1 Water**

Water is used periodically to clean the separation equipment. The frequency of cleaning and the volumes of water used vary depending on the product and the equipment. Sometimes the water can be reprocessed. Waste water is produced from cleaning the equipment, as well as in the form of separated waste products from the operational process, which will contain dissolved organic material and SS.

#### **3.2.12.2 Solid output**

Centrifugal separator sludges may sometimes be re-used in the process or may otherwise have to be disposed of. The sludges produced contain organic and inorganic material.

#### **3.2.12.3 Energy**

Centrifugation uses significant amounts of energy. When sedimentation is used, electrical energy is required for pumping operations.

#### **3.2.12.4 Noise**

The operation of centrifuges may involve relatively high levels of noise in close proximity to the machines and, therefore, suitable control measures need to be put in place.

### **3.2.13 Filtration (C.5)**

#### **3.2.13.1 Water**

Depending on the end purpose of the filtration operation, the process may result in waste water containing dissolved organic material, SS and FOG.

#### **3.2.13.2 Air emissions**

The air discharge from the vacuum pump during vacuum filtration may contain dust. These emissions are minor in quantity.

### 3.2.13.3 Solid output

Filter residues arise and require a suitable method of recovery or disposal, e.g. bleaching earth in edible oil refining or diatomaceous earth in a brewery.

### 3.2.13.4 Energy

Pumping requires electrical energy.

## 3.2.14 Membrane separation (C.6)

### 3.2.14.1 Water

Water is used periodically to clean the separation equipment. The frequency of cleaning and the volumes of water used vary depending on the product and equipment. Waste water is produced from washing as well as in the form of separated waste products from the process, and contains dissolved organic material and SS.

### 3.2.14.2 Energy

Membrane separation is a pressure driven process, so electrical energy is required. In electro dialysis, electrical energy is required for the transport of ions.

## 3.2.15 Crystallisation (C.7)

### 3.2.15.1 Water

In crystallisation operations, water is used for cooling and is normally recirculated. Depending on the cooling requirements, water is recirculated via chilling units, cooling towers or cooling ponds. Waste water containing soluble organic material is generated after the removal of crystals.

### 3.2.15.2 Solid output

In the refinery process, active carbon is used if required. Spent active carbon is either regenerated or disposed of as waste.

### 3.2.15.3 Energy

Electricity is needed to power the pumps and drives. Energy is needed for the cooling system.

## 3.2.16 Removal of free fatty acids by neutralisation (C.8)

### 3.2.16.1 Water

The neutralisation process requires cooling water. The waste water that results from a combined neutralisation and soap-stock splitting has a temperature of about 100 °C, high acidity and contains salts of sodium sulphate or sodium chloride and sodium phosphate in high concentrations. If citric acid is used, this increases the BOD load of the waste water. The disposal of process waste water with high concentrations of sulphates (>2000 mg/l) into a MWWTP may cause corrosion of the concrete. Phosphorus levels may be high. The waste water may also contain FOG.

### 3.2.16.2 Air emissions

The soap-stock acidulation system may be a source of odour.

### **3.2.16.3 Solid output**

Fatty acids are considered a by-product. The treatment of a neutralisation waste water can produce high amounts of sludge, due to the presence of phosphates and/or sulphates. The waste water may have high salt concentrations.

### **3.2.16.4 Energy**

The steam generation required as the main source of energy for neutralisation and soap-stock splitting consumes significant amounts of energy.

## **3.2.17 Bleaching (C.9)**

### **3.2.17.1 Air emissions**

There may be odour emissions.

### **3.2.17.2 Solid output**

The solid output from bleaching is known as spent earth. Due to its high oil content, there is a risk of self-ignition. The spent earth of an oil refinery can be added to the meal formed by crushing to make a by-product. The spent earth used for bleaching hardened oils can also be added to the meal, as long as it does not contain nickel and/or activated carbon. Otherwise, as it has a high calorific value, it is used as an energy source, e.g. in the production of concrete or to produce biogas.

### **3.2.17.3 Energy**

Steam is needed for oil recovery from the spent bleaching earth. The oil and spent bleaching earth are heated by steam during the bleaching process.

## **3.2.18 Deodorisation by steam stripping (C.10)**

### **3.2.18.1 Water**

Water is used for cooling the condensers. The water from the barometric condensers may be polluted. In a once-through barometric condenser, the heat load to the surface water is equivalent to the steam consumption in the vacuum system. The waste water produced contains soluble organic material, SS and FOG.

### **3.2.18.2 Air emissions**

Vacuum pumps release organic compounds that may cause odour problems.

### **3.2.18.3 Solid output**

Fatty acids and distillates are produced by this process. These are, in most cases, considered as by-products.

### **3.2.18.4 Energy**

For this processing technique, energy is needed in the form of steam and electricity. The electrical energy consumption ranges from 17 – 42 kWh/t product (60 – 150 MJ/t), and steam consumption from 115 – 310 kWh/t product (420 – 1120 MJ/t).

### 3.2.18.5 Noise

Noise issues may arise from the cooling tower fans.

### 3.2.19 Decolourisation (C.11)

#### 3.2.19.1 Water

During start-up and shut-down, low volumes of aqueous product may be discharged which contain low quantities of solid matter. In some cases this discharge is reprocessed/re-used in the process. However, it is not always economical to concentrate this material, in which case it is discharged as waste water. This waste water may contain dissolved organic material, SS and dissolved solids.

#### 3.2.19.2 Solid output

The decolourisation process produces a filter residue consisting of the active material, any filter aid used and some residual product. This solid output is sometimes sent to landfill or for landspreading/composting depending on its nature. Depending on the type of process/product, this solid output can also be used as animal feed.

#### 3.2.19.3 Energy

Any heating of the product used to meet the optimum conditions for the operation can usually be recovered by normal heat recovery systems. The regeneration of activated carbon involves kilning at elevated temperatures in the absence of oxygen. This is mainly done off site by specialised companies.

### 3.2.20 Distillation (C.12)

#### 3.2.20.1 Water

A residual liquid such as stillage, pot ale, spent lees and spent wash, is discharged from the stills. The waste water contains SS and very high BOD levels. Where recovery systems exist, a proportion of the stillage may be re-used.

#### 3.2.20.2 Air emissions

Emissions to air include dust, VOCs and odour. There may be minor emissions of uncondensable volatiles, mainly carbon dioxide and ethanol from column stills. There are no issues for pot stills.

#### 3.2.20.3 Solid output

Concentrated stillage or dried stillage may be used in animal feed, as a feedstock in sugar and grain-based production, sent for landspreading or otherwise disposed of as waste. Solid outputs are also used for methane production, the gas being used for energy production. This can improve the energy balance in the distillation process.

#### 3.2.20.4 Energy

The distillation tower is heated by steam. For pot stills, 12 to 13 kWh per litre of pure alcohol is required.

### 3.2.20.5 Noise

Some of the production equipment may emit high noise levels, e.g. during the concentration of stillage or the dehydration of alcohol by molecular sieve adsorption.

### 3.2.21 Soaking (D.1)

#### 3.2.21.1 Water

For soaking, water is required and consequently some waste water containing dissolved organic material and SS is produced.

#### 3.2.21.2 Solid output

Some dirt can be produced, although this is usually removed during soaking. Organic solid output may also be produced.

### 3.2.22 Dissolving (D.2)

#### 3.2.22.1 Water

Waste water is generated during cleaning. This waste water may contain product residues, e.g. powder and oil from rinsing, resulting in dissolved organic material, dissolved solids and SS in the waste water.

#### 3.2.22.2 Air emissions

Dust emissions may occur during bag tipping. These emissions are typically minor and generally remain inside buildings.

#### 3.2.22.3 Energy

During the dissolving process, steam and electricity are used.

### 3.2.23 Solubilisation/alkalising (D.3)

#### 3.2.23.1 Water

Waste water is generated from the cleaning of equipment and typically contains soluble organic material, SS and FOG.

#### 3.2.23.2 Air emissions

Air emissions typically consist of water vapour containing low concentrations of VOCs and dust. Odour may also be a problem.

#### 3.2.23.3 Energy

An example of the typical energy requirements per tonne of cocoa is shown in Table 3.8.

|                 | Electrical power<br>(kJ/kg) | Electrical power<br>(kWh/kg) | Steam<br>(kg/t) | Steam<br>(kWh/t) |
|-----------------|-----------------------------|------------------------------|-----------------|------------------|
| Liquid process  | 35 – 70                     | 0.010 – 0.019                | 300 – 500       | 233 – 389        |
| Nips alkalising | 35 – 550                    | 0.010 – 0.153                | 700 – 1000      | 548 – 778        |

**Table 3.8: Typical energy requirement per tonne of cocoa**  
[1, CIAA, 2002]

### **3.2.24 Fermentation (D.4)**

#### **3.2.24.1 Water**

Water is used for cooling the fermentation vessels. Usually, cooling water from the cooling towers or a dedicated once-through system is used. Waste water is generated from cleaning the equipment and vessels. This generally contains raw material and fermented product residues. Yeast, as an organic product, has a high COD and SS content and is a major contributor, along with the carrying liquid phase, to the COD load of the waste water.

#### **3.2.24.2 Air emissions**

Emissions to the air are alcohol and CO<sub>2</sub>, which is a natural product of alcoholic fermentation. Within controlled fermentation processes, it is generally common practice to vent these emissions to the air, although recovery and re-use may also take place. Odour may also be a problem.

#### **3.2.24.3 Solid output**

Brewers' yeasts are a by-product, with common secondary uses as food products or animal feed.

#### **3.2.24.4 Energy**

Electrical energy is needed to circulate the cooling water.

### **3.2.25 Coagulation (D.5)**

#### **3.2.25.1 Water**

Water is needed for curd washing. Waste water is generated during the cleaning of the equipment and contains dissolved organic material and SS.

#### **3.2.25.2 Energy**

Steam energy is needed for heat treatment and electricity is needed for cooling.

### **3.2.26 Germination (D.6)**

#### **3.2.26.1 Water**

Some water is required for the humidification of air.

#### **3.2.26.2 Air emissions**

The air from the germination process is loaded with water vapour and minor amounts of VOCs, which may emit odour.

#### **3.2.26.3 Energy**

Energy is needed for conditioning and circulating the air.

### **3.2.27 Brining/curing and pickling (D.7)**

#### **3.2.27.1 Water**

Brine that is discarded after use, or excess brine from immersion baths, is discharged as waste water. The quantity discharged depends on the method of brining or curing used. This waste water contains salt, curing salts and other ingredients, and also soluble product components, such as protein which is exuded from the product during brining. The cleaning of premises and equipment also generates waste water containing residual curing ingredients, product residues, dissolved organic material, dissolved solids and SS.

### **3.2.28 Smoking (D.8)**

#### **3.2.28.1 Water**

The waste water generated during cleaning contains soluble organic material, residues from the chemical components of the vapour and the liquid phases of the smoke, as well as cleaning chemicals.

#### **3.2.28.2 Air emissions**

Strong odours are produced during the smoking and drying operations. Emission is much higher during the smoking stage than during the drying step. The vented smoke also contains VOCs. Some installations remove odours from the smoke before it is emitted to the air.

#### **3.2.28.3 Solid output**

Ashes from wood.

#### **3.2.28.4 Energy**

Energy is needed for smoke generation and for heating and drying.

### **3.2.29 Hardening (D.9)**

#### **3.2.29.1 Water**

Water is used for cooling purposes because the end-product should not be warmer than 100 °C. Steam, from demineralised water, is necessary to heat the autoclaves and/or reactors. Water is also used for cleaning the installation. The water consumption is between 0.8 and 2 m<sup>3</sup> of drinking water and/or demineralised water per tonne of product. This depends on the type of cooling system. Cooling water consumption is between 2 and 5 m<sup>3</sup>/t of product [109, CIAA-FEDIOL, 2002]. The cleaning water from these operations can contain traces of nickel that can accumulate in, and thus contaminate, the sludge of a WWTP. The waste water produced contains soluble organic material, SS and FOG.

#### **3.2.29.2 Air emissions**

Hydrogen emissions, e.g. in the case of installation breakdown, have an associated explosion/fire risk.

#### **3.2.29.3 Solid output**

The solid output contains the spent nickel and specialised companies can recycle this.

#### **3.2.29.4 Energy**

Energy is supplied as steam and electricity. Total energy consumption is between 110 to 280 kWh/t product (400 and 1000 MJ/t).

#### **3.2.29.5 Noise**

Noise issues may arise from cooling towers, compressors or vacuum systems.

### **3.2.30 Sulphitation (D.10)**

#### **3.2.30.1 Air emissions**

A substance of environmental concern is SO<sub>2</sub>, however, it is readily absorbed by the liquid to be treated, e.g. wine, and actual residual emissions are extremely low.

### **3.2.31 Carbonation (D.11)**

#### **3.2.31.1 Air emissions**

Excess CO<sub>2</sub> is vented to the air. If a limekiln is used, then there is CO emitted due to the inevitable incomplete combustion within the kiln. SO<sub>2</sub> and NO<sub>x</sub> combustion products also occur and are vented to the air accompanied by small amounts of dust. Lime hydrators, used in conjunction with kilns, will also emit small quantities of dust. There is usually an over-pressure vent on the kiln. The normal kiln exhaust gases are washed before being introduced in the process. Exhaust gases and vapours from the carbonation vessels contain NH<sub>3</sub>, CO and other malodorous compounds.

#### **3.2.31.2 Solid output**

Any precipitate formed during the carbonation is separated out from the sugar juice and is sometimes sent for landspreading. Residues from lime production and hydrating are sent to landfill or, e.g. used for road paving or road foundations.

#### **3.2.31.3 Noise**

If a limekiln is used, then the charging of limestone and coke may produce noise off site.

### **3.2.32 Carbonation (D.12)**

#### **3.2.32.1 Air emissions**

There is risk of accidental releases of CO<sub>2</sub>.

#### **3.2.32.2 Energy**

Energy is required to operate heat-exchangers and coolers.

### **3.2.33 Coating/spraying/enrobing/agglomeration/encapsulation (D.13)**

#### **3.2.33.1 Water**

Waste water is produced from the cleaning of the equipment. This will contain product residues consisting of dissolved organic material, SS and FOG.

**3.2.33.2 Air emissions**

Odour is produced.

**3.2.33.3 Solid output**

Solid output is produced which contains organic and inorganic material.

**3.2.34 Ageing (D.14)****3.2.34.1 Water**

Water is used for cleaning and this generates waste water which contains soluble organic material and SS.

**3.2.34.2 Air emissions**

Emissions to air include odour and VOCs.

**3.2.34.3 Solid output**

Solid output is produced which contains organic material. Waste from packaging may also be produced.

**3.2.35 Melting (E.1)****3.2.35.1 Water**

Waste water is generated during cleaning. This waste water generally has a high BOD level and may contain SS and FOG.

**3.2.35.2 Air emissions**

Odour emissions may occur in the dry melting process of meat residues, for example.

**3.2.35.3 Solid output**

In some melting processes, a solid phase remains. This is considered to be a by-product.

**3.2.35.4 Energy**

In the melting process, the use of steam is the main energy component.

**3.2.36 Blanching (E.2)****3.2.36.1 Water**

The leaching of sugars, starches and other soluble organic compounds from the raw fruit or vegetables into the blanching water results in high BOD, SS and dissolved solids levels. As blanching water is normally re-used/recycled, the volume of waste water from blanching is normally relatively small. However, this tends to concentrate pollutants in the waste water.

### 3.2.36.2 Air emissions

Steam/water vapour may be discharged to the air. Depending on the raw material being blanched, the exhaust air may contain low levels of VOCs, which may generate a low level of odour.

### 3.2.36.3 Solid output

Some solid organic material may accumulate in the bottom of the blanchers. This needs to be removed periodically.

### 3.2.36.4 Energy

Energy is used for heating the blanching water.

## 3.2.37 Cooking and boiling (E.3)

### 3.2.37.1 Water

Waste water is generated during processing and cleaning and contains product residues. The waste water produced also contains dissolved organic material, SS, FOG, dissolved solids and possibly nitrate, nitrite, ammonia and phosphate.

### 3.2.37.2 Air emissions

Emissions to air include odour and VOCs.

### 3.2.37.3 Solid output

Solid output containing organic material and FOG may result from the cleaning of cooking equipment.

### 3.2.37.4 Energy

Cooking and boiling uses energy to provide heat, e.g. for steam production.

## 3.2.38 Baking (E.4)

### 3.2.38.1 Water

Waste water is produced which contains soluble organic material, SS and FOG.

### 3.2.38.2 Air emissions

During baking, VOCs, odour and CO<sub>2</sub> are emitted to the air together with water vapour. An example bakery with a production capacity of 340 tonnes per day has an air emission from the ovens containing ethanol, at a concentration of approximately 1 g/Nm<sup>3</sup>. The proposed UK environmental benchmark for the annual average release of ethanol is 0.0192 g/Nm<sup>3</sup> and the hourly mean benchmark is 0.576 g/Nm<sup>3</sup> [102, UK, 2002].

### 3.2.38.3 Solid output

Solid output is produced which contains organic material. Some residues may result from dry cleaning.

### 3.2.38.4 Energy

Ovens are heated using either electrical energy or fuel in the form of natural gas or oil. For infrared ovens, special types of burners are applied. The energy usage for baking normally ranges from 0.125 – 0.167 kWh/kg of product (450 – 600 kJ/kg).

## 3.2.39 Roasting (E.5)

### 3.2.39.1 Water

Small amounts of water are used for quenching, e.g. roasted coffee, cereals and chicory. This water is partly evaporated and emitted into the air and partly absorbed by the product, e.g. coffee.

### 3.2.39.2 Air emissions

The outlet of both the roaster and the cooler contain odour components, CO<sub>2</sub>, NO<sub>2</sub> and VOCs. The concentration of VOCs causing this odour is higher for the roaster outlet than for the cooler outlet. VOC levels are higher when the product is roasted to a higher degree, e.g. when the product temperature at the end of the roasting process is higher. The difference in emissions between a low roasted and a very high, i.e. very dark, roasted product can be as much as a factor 10. For batch roasters, the highest concentrations are emitted just before the end of the roasting process. In continuous roasters, the emissions are also continuous. The absolute level of VOCs depends on the product temperature at the end of the roasting; the amount of air used for roasting, which has a diluting effect; the product itself and the roasting time. The emissions of organic substances and the organic roasting losses result from the decomposition or chemical reaction of, e.g. chlorogenic acid, citric acid, oxalic acid, crude proteins and trigonellin. Nitrogen-based compounds, e.g. amines and sulphur-based compounds, e.g. mercaptans contribute considerably to the odours emitted by coffee roasting installations. In the raw gas, odorant contents of up to 300000 OU/Nm<sup>3</sup> have been measured. TOC mass concentrations of up to 10000 mg/Nm<sup>3</sup> are produced. Ammonia, nitrogen oxides, carbon dioxide and carbon monoxide are also produced. Dust emissions may also be a problem.

### 3.2.39.3 Solid output

Solid outputs include, e.g. the skins of coffee beans. For coffee, the solid output can be between 0.1 to 1.5 % of the amount of green coffee.

### 3.2.39.4 Energy

The actual energy consumption depends on the type of roaster being used and also on the layout of the flue-gas system.

## 3.2.40 Frying (E.6)

### 3.2.40.1 Water

Waste water arises from the cleaning of equipment and contains FOG, in the form of free fat and emulsified fat as well as other product residues. The waste water also contains SS, dissolved organic material and acid/alkali solutions.

### 3.2.40.2 Air emissions

The air above a fryer is extracted to prevent emissions into the working environment. This exhaust air may contain VOCs, such as the breakdown products of the edible oil. Odour may also be an issue associated with the exhaust.

### **3.2.40.3 Solid output**

Oil which has reached the end of its useful life needs to be disposed of. Inorganic material may also be contained in the solid output.

### **3.2.40.4 Energy**

The frying oven is usually oil-fired or steam heated.

## **3.2.41 Tempering (E.7)**

### **3.2.41.1 Water**

Water is used for the recirculating chilled water system for cooling. The waste water produced contains soluble organic material and SS.

### **3.2.41.2 Energy**

Electricity is needed for the pumps and drives and for the cooling system.

## **3.2.42 Pasteurisation, sterilisation and UHT (E.8)**

### **3.2.42.1 Water**

Water or other chilling media are required for cooling after heat treatment. Cooling after UHT treatment can be performed in two steps, i.e. firstly, by flash cooling to atmospheric pressure in flash vessels, followed by cooling with water.

In the case of aseptic or hot filling, there are product losses of both organic and inorganic deposits from the heat transfer surface. These are later discharged in the waste water during the cleaning of the equipment. In the case of heat treatment after canning or bottling, chlorinated cold water is required. This results in waste water containing dissolved organic material and SS.

### **3.2.42.2 Energy**

Energy, usually in the form of steam or hot water, is required for heat treatment. After heat treatment, energy can be recovered by heat-exchange in a recovery section. For the final cooling, a cooling medium is needed. Cooling can be accomplished by once-through cooling whereby the cooling water is cooled down in a cooling tower or with a recirculating chilled water system. The latter uses a mechanical refrigeration system, so energy is consumed.

## **3.2.43 Evaporation (liquid to liquid) (F.1)**

### **3.2.43.1 Water**

The removal of deposits during cleaning and product losses during start-ups and shut-downs contributes to the organic and inorganic load in the waste water. During evaporation, condensates from the product are also produced. Depending on their content, e.g. organic, inorganic and SS, these condensates can be re-used in the process or are treated in a WWTP. The final vapours are condensed in an open or closed condenser using cooling water. The waste water contains dissolved organic and inorganic matter and SS.

### **3.2.43.2 Air emissions**

Sometimes non-condensable gases are vented to the air to ensure efficient heat transfer. The environmental effects arising depend on the gases being vented. Dust and odour may also be a problem.

### 3.2.43.3 Energy

Steam requirements for single-stage evaporators range from 1.1 to 1.2 tonnes of steam per tonne of evaporated water. Energy requirements may be reduced when using multi-effect evaporators. In the case of double or third effect, the steam requirement lowers respectively to 0.6 - 0.7 and 0.4 tonnes of steam per tonne of evaporated water. The steam consumption can also be reduced by applying mechanical or thermal vapour recompression (see Sections 4.2.9.2.1 and 4.2.9.2.2) Sometimes exhaust gases can be used to recover energy from other processes such as drying (see Section 3.2.44).

### 3.2.43.4 Noise

Noise is often produced from the evaporation processes, in particular from the thermal compressor, the mechanical compressor, the steam ejectors and the high velocity of the fluids in the pipework. This can usually be managed by applying appropriate acoustic insulation. Noise is also generated in pumps due to cavitation.

## 3.2.44 Drying (liquid to solid) (F.2)

### 3.2.44.1 Water

The use of water is normally restricted to cleaning the equipment. The amount used greatly depends on the type of equipment. During cleaning, waste water is generated containing soluble organic material and SS. When air scrubbers are used, a waste water stream containing organic material such as fine dust is generated.

### 3.2.44.2 Air emissions

In hot air drying, a gas/vapour is generated and exhausted into the air. This gas/vapour may contain dust and VOCs, which originate from the product. This may cause an odour problem which might require treatment prior to discharge. If drying is done using direct gas or fuel fired burners, the exhaust gases might contain CO<sub>2</sub>, CO, SO<sub>2</sub>, NO<sub>x</sub>, depending on the heat source and burner type. Food safety requirements must be respected, especially when drying very sensitive products.

### 3.2.44.3 Solid output

A solid output may be generated when the equipment is emptied for a next batch or for cleaning. This solid output can consist of raw materials, product residues, and dust which has been recovered from the exhaust air. These solid products/dust can be recycled back into the process or sold as animal feed.

### 3.2.44.4 Energy

For the evaporation of water, theoretically 0.611 kWh/kg (2.2 MJ/kg) energy is required. In practice, due to energy losses in the process, the energy consumption for water evaporation ranges from 0.694 – 0.972 kWh/kg (2.5 to 3.5 MJ/kg).

### 3.2.44.5 Noise

Noise may arise from the air inlet and outlet of the driers. If sound baffles are used to reduce the noise at outlets, these baffles need to be checked periodically to remain effective.

### **3.2.45 Dehydration (solid to solid) (F.3)**

#### **3.2.45.1 Water**

Water may be used in cleaning the equipment, with the resultant waste water containing dissolved organic material and SS. Kilns for the drying of malt are cleaned dry.

#### **3.2.45.2 Air emissions**

In the hot-air dehydration process, air, with water vapour containing VOCs and dust, is released. If dehydration is done using direct-fired burners, the exhaust gases might also contain CO<sub>2</sub>, CO, SO<sub>2</sub>, and NO<sub>x</sub>, depending on the heat source and burner type. Depending on the type of raw material or product, the dust may be glutinous and wet, e.g. meal from oilseed processing. Dry dust can be filtered and wet dust can be recovered using cyclones. Odour may also be a problem.

#### **3.2.45.3 Solid output**

Solid organic material may be generated when equipment is emptied for a next batch or for cleaning. These outputs can consist of raw material, product residues and dust. These solid products/dust can be recycled back into the process or sold as animal feed.

#### **3.2.45.4 Energy**

For the evaporation of water, theoretically 0.611 kWh/kg (2.2 MJ/kg) energy is required. However, in practice, this very much depends on the type of drier used and can range from 0.556 – 1.08 kWh/kg (2.0 – 3.9 MJ/kg). Steam driers can have a considerably lower energy consumption if they consist of more effects (multiple effect evaporation). Sometimes exhaust gases from a combustion (CHP) plant are used to dry products, thereby reducing the direct energy consumption. The energy consumption for dehydration can be further reduced by increasing the dry substance content of the wet product. This can be achieved by pre-evaporation or by using special dewatering equipment.

#### **3.2.45.5 Noise**

Noise may arise from the air inlet and outlet of the driers.

### **3.2.46 Cooling, chilling and cold stabilisation (G.1)**

#### **3.2.46.1 Water**

Water may be used as the cooling medium in a once-through system. When cooling water is recirculated, closed-circuit cooling towers can be used for heat removal.

#### **3.2.46.2 Air emissions**

In cryogenic cooling, emissions of gaseous N<sub>2</sub> or CO<sub>2</sub> occur. Leaking refrigeration equipment can lead to emissions of refrigerant.

#### **3.2.46.3 Energy**

Electrical energy is needed to drive the pumps circulating the cooling water or the fans in air cooling. Mechanical refrigeration systems generally require 0.3 – 1.0 kWh power per cooling effect. However, overall, their energy consumption is significantly less than the total energy required for the manufacture and use of liquid N<sub>2</sub> or CO<sub>2</sub>.

#### 3.2.46.4 Noise

Noise issues may occur from fans and cooling towers.

### 3.2.47 Freezing (G.2)

#### 3.2.47.1 Water

Waste water, sometimes containing used brines may result from immersion freezing.

#### 3.2.47.2 Air emissions

In cryogenic freezing, emissions of gaseous N<sub>2</sub> or CO<sub>2</sub> are produced.

#### 3.2.47.3 Energy

Energy consumption is the major environmental issue. Electrical energy is needed for the fans for air circulation and the freezing system. For example, deep freezing is the most energy consuming step in the manufacture of deep frozen vegetables consuming 80 – 280 kWh<sub>e</sub>/t of frozen vegetable. Energy amounting to about 0.003 kWh/m<sup>2</sup> (0.01 MJ/m<sup>2</sup>) floor surface of tunnel/hour of operation is also consumed in the form of hot water. The energy consumption of a freezing tunnel depends on various factors and the following list uses the deep freezing of fruit and vegetables to illustrate these [32, Van Bael J., 1998]. Energy consumption depends on, e.g:

- the type of food to be frozen, e.g. voluminous vegetables, such as cauliflower florets are more difficult to freeze than small vegetables such as peas or diced carrots
- the temperature of the food at the entrance to the freezing tunnel. The higher this temperature is, the more heat has to be removed from the food before it is frozen
- the mass flowrate of the food. The higher the flowrate, the higher the quantity of energy that needs to be removed, and the greater the demand for cold air in the tunnel
- the residence time, which also determines the demand for cold air in the freezing tunnel. The longer the residence time, the more chance the food has to freeze. The thickness of the layer of food is directly proportional to the required residence time
- the energy consumption which is determined by the airflow rates in the freezing tunnel. The higher the airflow rates, the better the heat-exchange between the evaporators and the air on one hand, and the air and the food on the other hand. Higher airflow rates lead to higher energy consumption by the fans and higher cooling loads for the freezing tunnel; the full output of the motors needs to be cooled
- the efficiency or the COP, which plays a role in the energy consumption of freezing tunnels. As explained earlier, the efficiency is mainly determined by the condensation and evaporator temperature.

The energy consumption per unit of weight of frozen product depends very much on the parameters set for the evaporator temperature, fan rating and product flowrate, and the condensation pressures and type of product being processed. Since many factors affect the specific energy consumption, it is, therefore, only possible to give broad ranges for consumption [32, Van Bael J., 1998].

#### 3.2.47.4 Noise

Noise issues may occur from the operation of fans.

### **3.2.48 Freeze-drying/lyophilisation (G.3)**

#### **3.2.48.1 Water**

The condensed water derived from the dried product is disposed of as waste water. The concentration depends on the original water content of the material and on the type of material that is being dried. The waste water contains dissolved organic material and SS.

#### **3.2.48.2 Energy**

For freeze-drying, mainly electrical energy is used.

### **3.2.49 Packing and filling (H.1)**

#### **3.2.49.1 Water**

Releases occur due to product spills. Waste water is generated, e.g. by cleaning glass containers and kegs. If returned refillable bottles are used, the waste water will also contain residual contents. Installation and equipment cleaning also produces waste water, which typically contains dissolved organic material and SS.

#### **3.2.49.2 Air emissions**

Dust emissions may be a problem.

#### **3.2.49.3 Solid output**

Solid waste includes cast-offs due to, e.g. packaging machine faults/inefficiencies during filling, and capping process waste, especially during machine start-ups and shut-downs. Processes such as glass bottle blowing are usually completed off site by suppliers but waste can result from breakages *in situ*. Bottle blowing of PET may be carried out on site using either PET pellets or supplied pre-forms. This produces waste from off-cuts. Aluminium or steel can cylinders and aluminium can ends are pre-manufactured, off site. Laminated cartons and pouches are formed on site. This results in waste from off-cuts. Small amounts of solid waste are produced from inks and from the cleaning of printing equipment. The lubrication of equipment and the transport systems also produce waste. Some packaging is recycled.

#### **3.2.49.4 Energy**

Energy is consumed by filling/capping/packing equipment and other associated activities.

#### **3.2.49.5 Noise**

Noise emissions may be a problem along bottle filling lines.

### **3.2.50 Gas flushing and storage under gas (H.2)**

#### **3.2.50.1 Air emissions**

Gas mixtures used in the above processes are all supplied to the packing installation either in premixed form or as individual gases that are mixed *in situ*. Gas emissions, e.g. CO<sub>2</sub>, may occur during the process or as a result of accidents.

### **3.2.51 Cleaning and disinfection (U.1)**

#### **3.2.51.1 Water**

Large quantities of water are required for cleaning and disinfection. In many installations, this is the main consumer of water, with the amount depending on the type and size of equipment to be cleaned and the materials processed. Cleaning and disinfection produces waste water. This typically contains soluble organic material, FOG, SS, nitrate, nitrite, ammonia and phosphate from product remnants and removed deposited soil. It also contains residues of cleaning agents, e.g. acid or alkali solutions. In principle, the cleaning and disinfection agents that are used are discharged via the waste water, either in their original state or as reaction products.

#### **3.2.51.2 Solid output**

Product residues may be recovered during cleaning.

#### **3.2.51.3 Energy**

Cleaning is commonly carried out at elevated temperatures, which, therefore, requires the use of energy to heat water and produce steam.

### **3.2.52 Energy generation and consumption (U.2)**

#### **3.2.52.1 Water**

Boiler treatment chemicals, silica and other soluble minerals are concentrated within boilers. They are removed by blowing down the boiler at a rate of 1 % to more than 10 % of the steam production rate. The blowdown water is discharged and treated either in an on-site or off-site WWTP. Blowdown needs to take place to maintain the efficient, and ultimately safe, operation of the boiler.

#### **3.2.52.2 Air emissions**

The main products resulting from the combustion process are CO<sub>2</sub> and water vapour. CO<sub>2</sub> emissions from coal firing are almost twice as those from natural gas. The contaminants generated and emitted depend on the fuel type, combustion process and combustion plant design. These are SO<sub>2</sub>, CO, NO<sub>x</sub> and dust.

Emissions of SO<sub>2</sub> are a result of the sulphur content of the fuel. Gas has only trace amounts of sulphur. Gasoil has up to 0.1 % by weight of sulphur. Coal has between 0.5 % and 2.5 % by weight of sulphur. Fuel oil may have up to 3.5 % by weight of sulphur.

Emissions of NO<sub>x</sub> depend, not only on the fuel, but also on the inherent design of the combustion unit and the flame temperature. Gas, generally, does not contain any significant amounts of nitrogen compounds but will produce NO<sub>x</sub> from the oxidation of the nitrogen in the combustion air. Therefore, NO<sub>x</sub> from gas combustion is the lowest of any fossil fuel. NO<sub>x</sub> emissions may be reduced by steam injection into the burning chamber of the gas turbine or by using low NO<sub>x</sub> burners.

When the product is heated by direct contact with combustion gases, VOCs and odours are released with the process air. The heat released at a chimney depends on the fuel type and plant design. The consumption of purchased electricity does not cause emissions at FDM installations as the emissions take place at the power station. Information about emissions at large combustion plants, i.e. those with a rated thermal input exceeding 50 MW, is available in the "Large combustion plants BREF" [220, EC, 2003].

### **3.2.52.3 Solid output**

Ashes from solid fuel fired boilers and scale and inert soot deposits which are removed during periodic boiler maintenance and cleaning, are produced. They are sent for landfill.

### **3.2.52.4 Noise**

Normal boiler operations do not give rise to noise outside the installation, but this depends on the measures taken to contain the noise and the proximity of neighbouring premises. During process interruptions, and during periods of testing and commissioning, there may be short periods when the boiler safety relief valve operates. This effect is likely to be local to the installation but could be a source of nuisance during that period. Large relief valves can be provided with silencers.

## **3.2.53 Water use (U.3)**

### **3.2.53.1 Water**

Waste water from water regeneration and residues from other processes are discharged to water. Minimisation of water consumption by process optimisation and water recycling can be applied.

### **3.2.53.2 Solid output**

Mineral sludges and spent resins from water treatment processes need to be disposed of.

## **3.2.54 Vacuum generation (U.4)**

### **3.2.54.1 Water**

Water is used in water-ring type vacuum pumps for cooling and for sealing. To reduce water consumption, the water is normally recirculated in closed-circuit systems with a bleed off determined by the condensable matter. Waste water is produced which contains soluble organic material.

If steam jet ejectors are used for vacuum production, not only the media coming from the evacuated plant has to be condensed, but also the driving steam of the jet ejector. This is normally done in spray condensers. Here, water is used to condense the steam along with any volatiles carried over. For large installations, the volume of water used to condense the steam can be significant, i.e. during refining of sugar or edible oil. The volatile material carried over is condensed in the water thereby increasing the level of dissolved organic material. To reduce water consumption, water can be recirculated over cooling towers. In this case a bleed from the system is required for the condensed steam. This can lead to a concentration of the organic material condensed in the water. With indirect condensers or heat-exchangers, the volume of condensate is equivalent to the condensed live steam and other condensable matter, and will contain any organic volatiles carried over. With chilling or freezing systems, the volume of condensate is reduced further.

### **3.2.54.2 Air emissions**

Depending on the material being processed, air evacuated by vacuum pumps may contain volatile material, which, if not properly controlled, may result in odour problems.

Non-condensable material may be discharged into the air with steam jet ejectors. Depending on the material being processed, this discharge may result in odour emissions. If condenser water is recirculated over cooling towers, the drift/mist from the towers may result in odour emissions. Indirect recirculation with heat-exchangers with two cycles may be used in this case. Heat-exchangers have to be cleaned regularly.

### **3.2.54.3 Energy**

The energy usage will depend on the type of compressor used, the absolute pressure to be achieved and the size of the system. For large operations, the consumption can be reasonably high.

### **3.2.54.4 Noise**

Noise may occur due to the operation of the fans associated with the cooling towers.

## **3.2.55 Refrigeration (U.5)**

### **3.2.55.1 Water**

Water consumption can be significant when water is used as the cooling medium for the condenser in a once-through system. Recirculating the cooling water over a cooling tower reduces water consumption. Accidental release of liquid ammonia needs to be prevented.

### **3.2.55.2 Air emissions**

Refrigeration equipment which contains mainly NH<sub>3</sub> or (H)CFCs does not emit refrigerants, if properly operated and maintained, as the systems are closed. An accidental breakage or leakage could cause releases into the atmosphere, so the risk of an accident needs to be minimised.

### **3.2.55.3 Energy**

Refrigeration equipment needs a high electricity input.

### **3.2.55.4 Noise**

Noise produced by the compressors of refrigeration equipment may be a problem.

## **3.2.56 Compressed air generation (U.6)**

### **3.2.56.1 Air emissions**

Air emissions are generally minimised due to the use of filters to remove oil and other impurities to ensure that the compressed air is of food grade quality.

### **3.2.56.2 Energy**

Energy is consumed in the compressor.

### **3.2.56.3 Noise**

Noise emissions can be a problem.

## **3.3 Consumption and emission levels in some individual FDM sectors**

Unit operations in specific sectors are described in Section 2.2.

Table 3.9 shows a summary of reported water consumption and waste water volumes for some of the FDM sectors. Some of the consumption and emission values are inconsistent.

| Sector                                     | Water consumption                         | Waste water volume            | Unit | Source  |   |
|--|---|-------------------------------|------|---|---|
| <b>Meat and poultry</b>                    | 2 – 20 m <sup>3</sup> /t                  | 10 – 25 m <sup>3</sup> /t     | **   | [41, Nordic Council of Ministers, 2001, 89, Italian contribution, 2001]   |   |
| <b>Fish</b>                                |   |                               |      |   |   |
| Herring filleting                          | 3.3 – 10 m <sup>3</sup> /t                | 2 – 40 m <sup>3</sup> /t      | **   | [27, ATV, 2000, 28, Nordic Council of Ministers, 1997]  |   |
| Mackerel                                   | 20 – 32 m <sup>3</sup> /t                 |                               |      |   |   |
| White fish                                 | 4.8 – 9.8 m <sup>3</sup> /t               |                               |      |   |   |
| Shrimp processing                          | 23 – 32 m <sup>3</sup> /t                 |                               |      |   |   |
| <b>Fruit and vegetable<sup>1</sup></b>     |   |                               |      |   |   |
| Canned fruit                               | 2.5 – 4.0 m <sup>3</sup> /t               | 11 – 23 m <sup>3</sup> /t     | *    | [5, Derden A Vercaemst P and Dijkmans R, 1999, 74, Greek Ministry for the Environment, 2001, 134, AWARENET, 2002, 140, World Bank (IBRD), et al., 1998] |   |
| Fruit juices                               | 6.5 m <sup>3</sup> /t                     |                               |      |   |   |
| Canned vegetables                          | 3.5 – 6.0 m <sup>3</sup> /t               |                               |      |   |   |
| Frozen vegetables                          | 5.0 – 8.5 m <sup>3</sup> /t               |                               |      |   |   |
| Deep frozen vegetables                     | 2.5 – 5.0 m <sup>3</sup> /t               |                               |      |   |   |
| Preserved vegetables                       | 5.9 – 11 m <sup>3</sup> /t                |                               |      |   |   |
| Potato                                     | 2.4 – 9.0 m <sup>3</sup> /t               |                               |      |   |   |
| Jams                                       | 6 m <sup>3</sup> /t                       |                               |      |   |   |
| Baby food                                  | 6.0 – 9.0 m <sup>3</sup> /t               |                               |      |   |   |
| <b>Starch</b>                              |   |                               |      |   |   |
| Maize                                      | 1.7 – 3 m <sup>3</sup> /t                 | 1.4 m <sup>3</sup> /t         | **   | [115, CIAA-AAC-UFE, 2002, 152, Austria, 2002]   |   |
| Wheat                                      | 1.7 – 2.5 m <sup>3</sup> /t               | 1.8 m <sup>3</sup> /t         |      |   |   |
| Potato                                     | 0.7 – 1.5 m <sup>3</sup> /t               | 2 m <sup>3</sup> /t           |      |   |   |
| <b>Dairy<sup>2</sup></b>                   |   | 1 – 5 l/kg                    |      | [152, Austria, 2002]  |   |
| Milk and yoghurt                           | 0.6 – 4.1 l/l                             |                               | **   | [42, Nordic Council of Ministers, et al., 2001]   |   |
| Cheese                                     | 1.2 – 3.8 l/l                             |                               |      |   |   |
| Milk powder, cheese and/or liquid products | 0.69 – 6.3 l/l                            |                               |      |   |   |
| Milk and yoghurt                           | 0.8 – 25 m <sup>3</sup> /t                |                               |      | 0.9 – 25 m <sup>3</sup> /t  | [160, European Dairy Association, 2002] |
| Cheese                                     | 1 – 60 m <sup>3</sup> /t                  |                               |      | 0.7 – 60 m <sup>3</sup> /t  |   |
| Milk powder, cheese and/or liquid products | 1.2 – 60 m <sup>3</sup> /t                |                               |      | 0.4 – 60 m <sup>3</sup> /t  |   |
| <b>Beer</b>                                | 0.32 – 1 m <sup>3</sup> /hl               | 0.24 – 0.9 m <sup>3</sup> /hl | *    | [69, Environment Agency of England and Wales, 2001, 199, Finland, 2003]   |   |
| <b>Sugar beet</b>                          | 0.23 <sup>3</sup> – 1.5 m <sup>3</sup> /t |                               | **   | [139, Nielsen E.H. Lehmann, 2002, 152, Austria, 2002]   |   |

| Sector               | Water consumption | Waste water volume | Unit | Source |
|----------------------|-------------------|--------------------|------|--------|
| <b>Vegetable oil</b> |                   |                    |      |        |

|   |                                       |  |    |  |  |
|---|---------------------------------------|--|----|--|--|
| Crude oil production  | 0.2 – 14 m <sup>3</sup> /t            | 0.2 – 14 m <sup>3</sup> /t               | ** | [65, Germany, 2002, 74, Greek Ministry for the Environment, 2001, 109, CIAA-FEDIOL, 2002, 134, AWARENET, 2002, 140, World Bank (IBRD), et al., 1998, 182, Germany, 2003, 185, CIAA-FEDIOL, 2004] |  |
| Chemical neutralisation   | 1 – 1.5 m <sup>3</sup> /t             | 1 – 1.5 m <sup>3</sup> /t                | *  |  |  |
| Deodorisation   | 10 – 30 m <sup>3</sup> /t             | 10 – 30 m <sup>3</sup> /t                |    |  |  |
| Hardening   | 2.2 – 7 m <sup>3</sup> /t             |  |    |  |  |
| Chemical refining   | 0.25 – 0.8 m <sup>3</sup> /t          | 14 – 35 m <sup>3</sup> /t                |    |  |  |
| Olive oil production  | 5 m <sup>3</sup> /t                   |  |    |  | [142, IMPEL, 2002]   |
| Traditional extraction  |                                       | 2 – 5 m <sup>3</sup> /t                  |    |  | [74, Greek Ministry for the Environment, 2001, 86, Junta de Andalucia and Agencia de Medio Ambiente, 1994] |
| Three-phase extraction  |                                       | 6 – 8 m <sup>3</sup> /t                  |    |  |  |
| Two-phase extraction  |                                       | 0.33 – 0.35 m <sup>3</sup> /t            |    |  |  |
| <b>Soft and alcoholic drinks</b>  | 6 – 14 m <sup>3</sup> /m <sup>3</sup> | 0.8 – 3.6 m <sup>3</sup> /m <sup>3</sup> |    |  | *  |
| <sup>1)</sup> Not applicable for tomato processing  |                                       |  |    |  |  |
| <sup>2)</sup> Not applicable for ice-cream processing   |                                       |  |    |  |  |
| <sup>3)</sup> Excluding cooling water   |                                       |  |    |  |  |
| *Per unit of product  |                                       |  |    |  |  |
| **Per unit of raw material  |                                       |  |    |  |  |
| This table summarises the data reported in Section 3.3. Some water consumption and waste water volumes are inconsistent. Information on applied processes and techniques, operating conditions and sampling methods not provided. |                                       |  |    |  |  |

**Table 3.9: Summary of water consumption and waste water volumes in the FDM sector**

### 3.3.1 Meat and poultry

#### 3.3.1.1 General information

##### 3.3.1.1.1 Water

The main environmental impact of meat and poultry manufacturing is the production of waste water. Significant quantities of water are used for washing and thawing meat. The reported water consumption is about 3 – 5 m<sup>3</sup>/t. The water used for thawing can be recirculated in a closed-circuit and used again [182, Germany, 2003]. Some other major water consuming steps are, e.g. pasteurising, sterilising, cooling, cleaning and disinfection. Stringent hygiene measures are applied to the cutting and chilling of carcasses which lead to relatively large quantities of waste water arising from equipment and installation cleaning.

##### 3.3.1.1.2 Air emissions

Air pollution is produced mainly due to the operation of boilers and smokers. Odour may be a nuisance. Refrigerants may leak causing air pollution.

##### 3.3.1.1.3 Solid output

Cutting and deboning meat and poultry produces bones, fat and skin. The use of animal by-products is regulated by Regulation 1774/2002/EC [188, EC, 2002]. Bones and fat may be used for, e.g. producing glue and detergents, or for producing gelatine which can be used, e.g. in some cases in the food or pharmaceutical industries. Some animal by-products must be disposed of as waste. Solid output may also be produced in packing operations such as waste packaging. Table 3.10 shows the proportion of carcasses considered to be by-products.

|       | By-products in cutting/deboning<br>(% of carcass weight) |         |         |
|-------|--|---------|---------|
|       | Beef   | Pig     | Poultry |
| Bones | 12   | 5 – 9.5 | 1 – 2   |
| Fat   |  | 3 – 6   | 6       |
| Skin  |  |         | 1 – 2   |

**Table 3.10: By-products in cutting and deboning meat**  
[134, AWARENET, 2002]

##### 3.3.1.1.4 Energy

A considerable amount of thermal energy is used in processes involving heat treatments such as boiling, cooking, pasteurising, sterilising drying and smoking. Other large energy consuming operations are chilling, freezing, thawing, and cleaning and disinfection.

#### 3.3.1.2 Meat and poultry production

##### 3.3.1.2.1 General information

This category covers a wide range of products and processing techniques, which are not practicable to consider individually.

All lines, equipment and process areas that are not in designated dry areas require wet cleaning, which generates waste water contaminated with the product, raw materials and cleaning chemicals. If scraps are washed down the drain, this will increase the COD, fat and SS content of the waste water. Cooking methods that involve direct contact between water or steam and product, produce waste water, as do cooling, chilling, freezing and filling operations.

Ingredients added to the meat may enter the waste water stream as a result of equipment washouts and spillage. Those used in large quantities, e.g. batter, breadcrumbs and cooking oil, can make a significant contribution to the BOD, TSS and FOG levels of the waste water.

It is reported that in the UK, fresh meats, especially poorer quality beef, are often treated with enzymes of plant or fungal origin to improve tenderness. The meat is either dipped in or sprayed with enzymes in solution. Enzymes are complex organic structures and unless operators ensure that the discharge of the enzyme solutions is kept to a minimum, they will carry a BOD contribution and may potentially affect the biology of a WWTP [13, Environment Agency of England and Wales, 2000]. Italy reports that the technique is not used there [184, Italy, 2003].

Table 3.11 summarises reported consumption and emission levels expressed per tonne of finished product in the Italian meat industry for cooked ham manufacturing. A flow sheet for cooked ham and shoulder production is given in Figure 2.4.

| Cooked ham     |  |                           |                  |                         |                   |                |
|----------------|--|---------------------------|------------------|-------------------------|-------------------|----------------|
| Unit operation |  | Water consumption         | Waste water load | Solid output            | Electrical energy | Thermal energy |
| No.            | Description  | (m <sup>3</sup> /t)       | (kg COD/t)       | (kg/t)                  | (kWh/t)           | (kg steam/t)   |
| A.1            | Materials handling and storage   |                           |                  | ** (plastic, cardboard) | *                 |                |
| A.2            | Sorting/screening, grading, dehulling, destemming/destalking and trimming  |                           |                  | * (meat)                | *                 |                |
| A.4<br>A.5     | Washing and thawing  | 0 – 15                    | **               | ** (fat)                | *                 | **             |
| B.1            | Cutting, slicing, chopping, mincing, pulping and pressing  |                           |                  | ** (meat)               | **                |                |
| B.2            | Mixing/blending, homogenisation and conching   |                           |                  | * (meat)                | *                 |                |
| B.4            | Forming/moulding and extruding   |                           |                  | * (meat)                | *                 |                |
| D.7            | Brining/curing and pickling  | 0.5                       | *                | ** (salt)               | *                 |                |
| D.8            | Smoking  |                           |                  | * (ash)                 |                   | **             |
| D.13           | Coating/spraying/enrobing/agglomeration/encapsulation  |                           |                  | * (dust)                |                   |                |
| E.3            | Cooking and boiling  | 2.5                       | ***              |                         | *                 | **             |
| E.5            | Roasting   |                           |                  | * (dust)                |                   | **             |
| E.6            | Frying   |                           |                  |                         |                   | **             |
| E.7            | Tempering  |                           |                  |                         |                   |                |
| E.8            | Pasteurisation, sterilisation and UHT  | *                         |                  |                         | *                 | **             |
| F.3            | Dehydration (solid to solid)   |                           |                  | * (dust)                | *                 | ***            |
| H.1            | Packing and filling  |                           |                  | * (plastic)             | **                |                |
| U.1            | Cleaning and disinfection  | **                        | **               |                         | *                 | *              |
| U.2            | Energy generation and consumption  | 0.25                      | *                |                         | **                |                |
| U.3            | Water use  |                           |                  | * (resins)              | *                 |                |
| U.4            | Vacuum generation  | *                         |                  |                         | *                 |                |
| U.5            | Refrigeration  |                           | **               |                         | **                |                |
|                | <b>Overall totals of typical installations</b><br>(all unit operations are not undertaken at each installation, so the totals are not the sum of the levels for each unit operation) | <b>4 – 18<sup>1</sup></b> | <b>10 – 21</b>   |                         |                   |                |

<sup>1)</sup> The higher value is valid for thawing with water  
 \*low consumption/emission  
 \*\*medium consumption/emission  
 \*\*\*high consumption/emission

**Table 3.11: Consumption and emission levels for cooked ham manufacturing in Italy [89, Italian contribution, 2001]**

### 3.3.1.2.2 Salami and sausage production

The main environmental factors relating to sausage manufacture concern the smoking and cooling processes. Wood smoke contains many compounds, which are of concern from a health point of view. They are, e.g. PAH, phenols, nitrite and N-nitroso compounds plus CO. Effective ventilation and exhaust is, therefore, necessary for kilns and rooms.

The smoke can produce odour problems in the surroundings. The odour strength in the emissions from a smoking kiln depends on the smoking process and the ventilation and drying conditions. Typical odour strength in untreated air is 5000 – 20000 OU/m<sup>3</sup>. A wet scrubber for cleaning the emissions from a smoking kiln will typically have an efficiency of 50 – 70 %, measured in OU/m<sup>3</sup>.

A carbon content of 1000 ppm has been measured in the exhaust from a modern warm smoking and cooking unit. After thermal oxidation at 815 °C and cooling to 26 °C, 5 ppm carbon was measured.

In a Norwegian investigation, the following levels for pollution from smoking were given per tonne of product: 0.3 kg CO, 0.15 kg inorganic particles, and 0.2 kg TOC. Furthermore, when examining a cooking/smoking cabinet, the following emissions were found after thermal oxidation of the smoke gases: 7 mg TOC/m<sup>3</sup> or 0.2 mg TOC/t of sausages. The gas did not contain CO.

Soot and tar compounds are deposited in the kilns and on smoking sticks and frames. This must be removed and this is often carried out with powerful alkaline detergents. Waste water from the smoking department can, therefore, contain a large number of chemical compounds.

Only very limited information is available about the use of resources and pollution from the manufacturing of salami and Vienna sausages. One reason is that a meat processing installation or a slaughterhouse may have many other activities than those mentioned here and that the companies do not have sufficient separation of the figures for consumption or emission levels for each product line. Table 3.12 shows reported specific consumption of water and energy, and emissions of waste water in salami and sausage production.

| Product      | Unit*             | Salami  | Salami | Various | Various sausages |
|--------------|-------------------|---------|--------|---------|------------------|
| Country      |                   | DK      | DK     | SE      | NO               |
| Water        | m <sup>3</sup> /t | 7.5     | 5.3    | 7.7     | 10               |
| Electricity  | kWh/t             | unknown | 1000   | 750     | 1300             |
| Heat         | kWh/t             | 1240    | 900    | 1000    | 450              |
| Recuperation | kWh/t             | unknown | 230    | 250     | unknown          |
| Total energy | kWh/t             | unknown | 2130   | 2000    | 1750             |
| BOD          | kg/t              |         | 4.7    | 15      | 8 – 10           |
| N            | g/t               |         | 300    |         |                  |
| P            | g/t               |         | 140    |         |                  |

\* t refers to tonnes of finished product

**Table 3.12: Specific consumption of water and energy and emissions of waste water in salami and sausage production**  
[41, Nordic Council of Ministers, 2001]

Table 3.13 summarises consumption and emission levels expressed per tonne of finished product reported for the Italian meat industry for preserved meat products manufacturing.

| Preserved products, e.g. sausages, dressed pork, ham, bacon, etc   |  |                            |                  |                         |                                |                |
|--|--|----------------------------|------------------|-------------------------|--------------------------------|----------------|
| Unit operation   |  | Water consumption          | Waste water load | Solid output            | Electrical energy              | Thermal energy |
| No.  | Description  | (m <sup>3</sup> /t)        | (kg COD/t)       | (kg/t)                  | (kWh/t)                        | (kg steam/t)   |
| A.1  | Materials handling and storage   |                            |                  | ** (plastic, cardboard) | *                              |                |
| A.2  | Sorting/screening, grading, dehulling, destemming/destalking and trimming  |                            |                  | *(meat)                 | *                              |                |
| A.4<br>A.5   | Washing and thawing  | *                          | ***              | **(fat)                 | *                              | **             |
| B.1  | Cutting, slicing, chopping, mincing, pulping and pressing  |                            |                  | **(meat)                | **                             |                |
| B.2  | Mixing/blending, homogenisation and conching   |                            |                  | *(meat)                 | *                              |                |
| B.4  | Forming/moulding and extruding   |                            |                  | *(meat)                 | *                              |                |
| D.7  | Brining/curing and pickling  |                            |                  | **(salt)                | *                              |                |
| D.8  | Smoking  |                            |                  |                         |                                | **             |
| F.3  | Dehydration (solid to solid)   |                            |                  | *(dust)                 | ***                            | ***            |
| H.1  | Packing and filling  |                            |                  | *(plastic)              | **                             |                |
| U.1  | Cleaning and disinfection  |                            | **               |                         | *                              | *              |
| U.2  | Energy generation and consumption  |                            | *                |                         | **                             |                |
| U.3  | Water use  |                            |                  | *(resins)               | *                              |                |
| U.4  | Vacuum generation  |                            |                  |                         | *                              |                |
| U.5  | Refrigeration  |                            | **               |                         | **                             |                |
|  | <b>Overall totals of typical installations</b><br>(all unit operations are not undertaken at each installation, so the totals are not the sum of the levels for each unit operation) | <b>10 – 20<sup>1</sup></b> | <b>20 – 25</b>   | <b>35 – 50</b>          | <b>2500 – 4000<sup>2</sup></b> |                |
| <sup>1)</sup> The higher value is valid for thawing with water<br><sup>2)</sup> Thermic + electric (1300 – 1400 kWh/t + 150 – 180 m <sup>3</sup> methane/t)<br>* low consumption/emission<br>** medium consumption/emission<br>*** high consumption/emission |  |                            |                  |                         |                                |                |

**Table 3.13: Consumption and emission levels for preserved meat products manufacturing in Italy [89, Italian contribution, 2001]**

### 3.3.1.3 Meat and poultry preservation

#### 3.3.1.3.1 Freezing

The only waste water generated from freezing is the overflow from the cooling system and freezer defrost water. See also Section 3.2.47.

#### 3.3.1.3.2 Curing

Salting and curing can introduce NaCl and Na<sub>2</sub>NO<sub>3</sub> into the waste water. Operators need to minimise over production of brine and also production out of specification brine. Not only would this constitute discharge of raw material, but excess/waste brine that would also have a detrimental effect on the WWTP if discharged in large quantities. Chloride brine is not reduced through a biological WWTP, apart from dilution. Traditional dry curing is practised by a number of small highly specialised companies. The process liberates small quantities of cooking waste water only.

Table 3.14 summarises consumption and emission levels expressed per tonne of finished product reported for the Italian meat industry for cured ham manufacturing. A flow sheet for cured ham production is given in Figure 2.5.

| Cured ham      |  |                           |                  |                         |                                |                |
|----------------|--|---------------------------|------------------|-------------------------|--------------------------------|----------------|
| Unit operation |  | Water consumption         | Waste water load | Solid output            | Electrical energy              | Thermal energy |
| No.            | Description  | (m <sup>3</sup> /t)       | (kg COD/t)       | (kg/t)                  | (kWh/t)                        | (kg steam/t)   |
| A.1            | Materials handling and storage   |                           |                  | ** (plastic, cardboard) | *                              |                |
| A.2            | Sorting/screening, grading, dehulling, destemming/destalking and trimming  |                           |                  | *(meat)                 | *                              |                |
| A.4            | Washing  | *(** <sup>1</sup> )       | ***              | ** (fat)                | *                              | **             |
| A.5            | Thawing  | *(** <sup>1</sup> )       | ***              | ** (fat)                | *                              | **             |
| B.1            | Cutting, slicing, chopping, mincing, pulping and pressing  |                           |                  | ** (meat)               | **                             |                |
| B.2            | Mixing/blending, homogenisation and conching   |                           |                  | *(meat)                 | *                              |                |
| B.4            | Forming/moulding and extruding   |                           |                  | *(meat)                 | *                              |                |
| D.7            | Brining/curing and pickling  |                           |                  | ** (salt)               | *                              |                |
| D.8            | Smoking ( <i>Spek and Hungarian salami</i> )   |                           |                  | *(ash)                  |                                | *              |
| F.3            | Dehydration (solid to solid)   | ***                       |                  | *(dust)                 | ***                            | ***            |
| H.1            | Packing and filling  |                           |                  | *(plastic)              | **                             |                |
| U.1            | Cleaning and disinfection  | **                        | **               |                         | *                              | *              |
| U.2            | Energy generation and consumption  | *                         | *                |                         | **                             |                |
| U.3            | Water use  |                           |                  |                         | *                              |                |
| U.4            | Vacuum generation  |                           |                  |                         | *                              |                |
| U.5            | Refrigeration  |                           | **               | *(resins)               | **                             |                |
|                | <b>Overall totals of typical installations</b><br>(all unit operations are not undertaken at each installation, so the totals are not the sum of the levels for each unit operation) | <b>2 – 20<sup>1</sup></b> | <b>20 – 25</b>   | <b>35 – 50</b>          | <b>2500 – 4000<sup>2</sup></b> |                |

<sup>1</sup>) The higher value is valid for thawing with water  
<sup>2</sup>) Thermic + electric (1300 – 1400 kWh/t + 150 – 180 m<sup>3</sup> methane/t)  
\* low consumption/emission  
\*\* medium consumption/emission  
\*\*\* high consumption/emission

**Table 3.14: Consumption and emission levels for cured ham manufacturing in Italy [89, Italian contribution, 2001]**

### 3.3.1.3.3 Smoking

Smoking is most often carried out on cured meat, however, it can be used on fresh meat products that are cooked before serving. Traditional smoking techniques rely on smouldering wood or sawdust and do not generate waste water. The mass production alternative is to use liquid smoke, prepared by the destructive distillation of wood and applied by spraying, dipping or atomisation. Contaminated waste water is produced when containers or equipment that have been in contact with liquid smoke are cleaned.

During the application of smoke to the meat products, a portion of the smoking ingredients condenses on the walls of the chambers. These tar-like layers are removed with hot water by an alkaline cleaning solution. This water is highly contaminated and should be disposed of separately; it has a COD level of 20000 – 100000 mg/l, pH of 12 – 14, phenol index of 20 - 480 mg/l, and PAH level of 1 – 5 mg/l.

### 3.3.1.3.4 Drying

Dried meats are produced by curing, followed by drying at low humidity. Unless odour abatement considerations make it necessary to condense water vapour from the drier flue-gases, no waste water is generated.

### 3.3.1.3.5 Canning

The use of hot water or direct steam heating for cooking, prior to canning produces waste water contaminated with fat, protein and fragments of meat. After canning, the meats must be heat-processed to achieve pasteurisation and shelf stability. Can cleaning, both before and after filling, and can cooling use considerable quantities of water.

Table 3.15 summarises consumption and emission levels expressed per tonne of finished product reported for the Italian meat industry for canned meat manufacturing. A flow sheet for canned meat production is given in Figure 2.3.

| Canned meat manufacturing  |   |                     |                  |                  |                   |                  |
|--|---|---------------------|------------------|------------------|-------------------|------------------|
| Unit operation   |   | Water consumption   | Waste water load | Solid output     | Electrical energy | Thermal energy   |
| No.  | Description   | (m <sup>3</sup> /t) | (kg COD/t)       | (kg/t)           | (kWh/t)           | (kg steam/t)     |
| A.1  | Materials handling and storage                            |                     |                  | 18 <sup>1</sup>  | 1 – 2             |                  |
| A.4<br>A.5   | Washing and thawing                                       | 6 – 12              | 1 – 2            |                  | 0.5 – 1.5         |                  |
| B.1  | Cutting, slicing, chopping, mincing, pulping and pressing |                     |                  |                  |                   |                  |
| E.8  | Pasteurisation, sterilisation and UHT                     | 1.5 – 3.5           |                  |                  | 2 – 4             | 800 – 900        |
| G.1  | Cooling, chilling and cold stabilisation                  | 1.5 – 3.5           |                  |                  |                   |                  |
| H.1  | Packing and filling                                       |                     | 1 – 2            | 0.7 <sup>2</sup> | 100 – 120         |                  |
| U.1  | Cleaning and disinfection                                 | 0.5 – 2.0           | 20               |                  | 5 – 10            |                  |
| U.2  | Energy generation and consumption                         | 1 – 2               |                  |                  |                   |                  |
| U.3  | Water use   |                     |                  | 1 <sup>3</sup>   |                   |                  |
| U.4  | Vacuum generation   |                     |                  |                  |                   |                  |
| U.5  | Refrigeration   |                     |                  |                  |                   |                  |
| <b>Overall totals of typical installations</b><br>(all unit operations are not undertaken at each installation, so the totals are not the sum of the levels for each unit operation) |   | <b>10 – 18</b>      | <b>20 – 25</b>   | <b>20 – 30</b>   | <b>150 – 400</b>  | <b>800 – 900</b> |
| <sup>1</sup> ) Plastic, cardboard<br><sup>2</sup> ) Cans<br><sup>3</sup> ) Sludge, resins  |   |                     |                  |                  |                   |                  |

**Table 3.15: Consumption and emission levels for canned meat in Italy [89, Italian contribution, 2001]**

## 3.3.2 Fish and shellfish

Major environmental impacts associated with fish processing operations are the high consumption of water, consumption of energy and the discharge of a waste water with a high organic concentration due to the presence of oils, proteins and SS. Waste water can also contain high levels of phosphates, nitrates and chloride. Noise, odour and solid wastes may also be concerns for some installations. In addition to this, due to its highly perishable nature when compared to other FDM products, if not properly refrigerated, product yield decreases and product losses contribute to the solid and liquid waste loads. These solids may be used in fish-meal production.

### 3.3.2.1 Water consumption

To meet quality and hygiene standards, the fish sector uses high quantities of water. It is mainly consumed for cleaning operations and washing, cooling, and transportation of fish. Fish canning and fish filleting consume large quantities of water, e.g. to clean and lubricate the filleting machinery. Typical figures for fresh water consumption are for thawing, about 1 m<sup>3</sup>/t fish; for filleting 5 to 11 m<sup>3</sup>/t fish, and for canning, 15 m<sup>3</sup>/t fish. Water is used for transporting fish and viscera, for cleaning the installation and the equipment, for washing raw materials and products, and for thawing. Reported water consumption and specific COD loads for traditional fish processing are summarised in Table 3.16.

| Production            | Water consumption<br>(m <sup>3</sup> /t raw fish) | COD<br>(kg/t raw fish) |
|-----------------------|---|------------------------|
| Herring filleting     | 3.3 – 10  | Up to 95               |
| Mackerel              |   |                        |
| Cleaning and head cut | 20  | 270                    |
| Thawing included      | 26 – 32   |                        |
| White fish processing |   |                        |
| Fresh fish            | 4.8   | 5 – 36                 |
| Thawing included      | 9.8   |                        |
| Shrimp processing     | 23 – 32   | 100 – 130              |

**Table 3.16: Specific water consumption and organic load in Nordic countries [28, Nordic Council of Ministers, 1997]**

### 3.3.2.2 Waste water

Most of the water consumed during fish processing becomes waste water. The process related waste water is produced in different processing steps, e.g. thawing, washing, head cutting, filleting, skinning and trimming, and in cleaning the equipment and the installation.

When frozen fish is used as a raw material, a thawing step is needed. The organic pollution of the waste water is relatively small. Scaling normally takes place in rotating perforated drums. Scales are flushed away using large amounts of water – 10 to 15 m<sup>3</sup>/t fish. Large volumes of waste water and organic pollution are generated. If the fillets are to be skinned, scaling is not necessary. In automated filleting and eviscerating processes, water is used to lubricate fish while passing through the machine. For some species such as mackerel, a warm caustic bath is necessary to remove the skin and the waste water needs to be neutralised before it is discharged.

Water is used for washing and rinsing the fish, giving rise to waste water carrying fish scraps and viscera. Viscera from oily fish contain high levels of oil and soluble matter, thus waste waters from their filleting normally have higher COD levels (3000 – 60000 mg/l) than those from white fish filleting (2000 – 6000 mg/l). The highly polluted waste water is generated due to the time that solid wastes are in contact with the water which contains blood and fat. In automated skinning, the fillet is pulled over a freezing drum. Water is used to clean and lubricate the machine. The skinning of fatty fish releases large quantities of oil to the waste water. The skinning process contributes about one third of the overall organic pollution in the waste water of filleting installations.

As the evisceration of fatty fish takes place at the processing installation, and white fish are eviscerated at sea, this also adds to the reason for the waste water having higher COD and TSS levels. Table 3.17 shows the reported waste water characteristics from fish filleting.

| Parameter                             | Filleting of herring         |                            | Filleting of cod                   |                  |
|---------------------------------------|------------------------------|----------------------------|------------------------------------|------------------|
|                                       | Average (kg/m <sup>3</sup> ) | Range (kg/m <sup>3</sup> ) | Concentration (kg/m <sup>3</sup> ) | Load (kg/t fish) |
| BOD <sub>7</sub>                      | 10000                        | 5000 – 20000               | 600 – 1300                         | 8 – 19           |
| Fat                                   | 12000                        | 2500 – 16000               | 50 – 70                            | 0.3 – 1.4        |
| Dry matter                            | 20000                        | 5000 – 28000               |                                    |                  |
| Protein                               | 6000                         |                            |                                    |                  |
| Total nitrogen                        |                              |                            | 100 – 600                          | 0.3 – 3.1        |
| Suspended solids                      |                              |                            |                                    | 1.6 – 11.3       |
| Water consumption (m <sup>3</sup> /t) |                              | 5                          |                                    |                  |

**Table 3.17: Waste water from fish filleting**  
[134, AWARENET, 2002]

In precooking, water is re-used several times and recovery can be made. About 3 – 4 g oil/kg fatty fish, protein and pieces of fish are released into the water with oil forming a layer on the surface. If the fish is made in brine, there is a high salt concentration in the waste water. Skin is removed from some species, such as mackerel, with the help of a warm caustic bath. Waste water is consequently alkaline and is treated by neutralisation.

The waste water contains blood, flesh, guts, soluble protein and waste material and is high in BOD, COD, TSS, FOG, and phosphates, as well as detergents and other cleaning agents.

Waste water production rates and characteristics depend highly on the production lines. Data for Germany are presented in Table 3.18.

| Production                        | Waste water production (m <sup>3</sup> /t) | SS (mg/l)  | BOD <sub>5</sub> (mg/l) | Fats* (mg/l) |
|-----------------------------------|--|------------|-------------------------|--------------|
| Herring                           | 17 – 40                                    | 220 – 1520 | 2300 – 4000             | 190 – 450    |
| Fresh fish                        | About 8                                    | 170 – 3650 | 1000 – 6250             | 46 – 2500    |
| Smoking of fish                   | About 8                                    | 14 – 845   | 1000 – 1700             | 24 – 180     |
| Salting of salmon                 | About 35                                   |            |                         |              |
| Deep frozen fish                  | 2 – 15                                     |            |                         |              |
| Thawing                           |  | 0 – 70     | 30 – 1800               | 4 – 46       |
| *expressed as petrolether extract |  |            |                         |              |

**Table 3.18: Typical waste water production rates and characteristics for fish processing in Germany**  
[27, ATV, 2000]

### 3.3.2.3 Solid output

The solid wastes generated during fish processing range between 20 – 60 % of the catch, comprising skin, guts, bones, heads, cephalopods, feathers and shells. For example, when the fish quality is poor, soft fillets can get caught in the skinning knife. This decreases the yield and increases the production of by-products and waste.

Part of the waste water and almost all of the solid output may be used for different purposes. Fatty acids and flavours may be recovered from cooking water. Rejected fish are used in animal feed or for production of fish-meal and fish-oil and used afterwards in foodstuff, animal feed and coatings.

By-products from the filleting, skinning, cutting and canning steps are used for:

- production of foodstuffs, e.g. fish-meal, ingredients, surimi, polyunsaturated fatty acids, gelatine and collagen
- production of animal feed, e.g. fish protein, fish silage, fish protein hydrolysate, petfood, fish-oil and solubles
- production of fertilisers such as fish solubles and fish protein hydrolysate
- production of pharmaceuticals such as gelatine and collagen
- production of coatings, e.g. fish-oil and pearl essence, and adhesives such as fish glue
- production of leather.

Fluid lost from the fish may be treated anaerobically to produce biogas. Heads, shells, intestines and scraps have different applications, such as:

- production of animal feed, e.g. fish-meal, crustacean meal for cats and astaxanthin for aquaculture
- production of foodstuff, e.g. fish-meal, chitin and chitosan
- production of flocculants for waste water treatment, e.g. chitin and chitosan
- production of pharmaceuticals, e.g. chitin and chitosan.

Figure 3.3 shows consumption and emission levels of the process steps in fish canning.

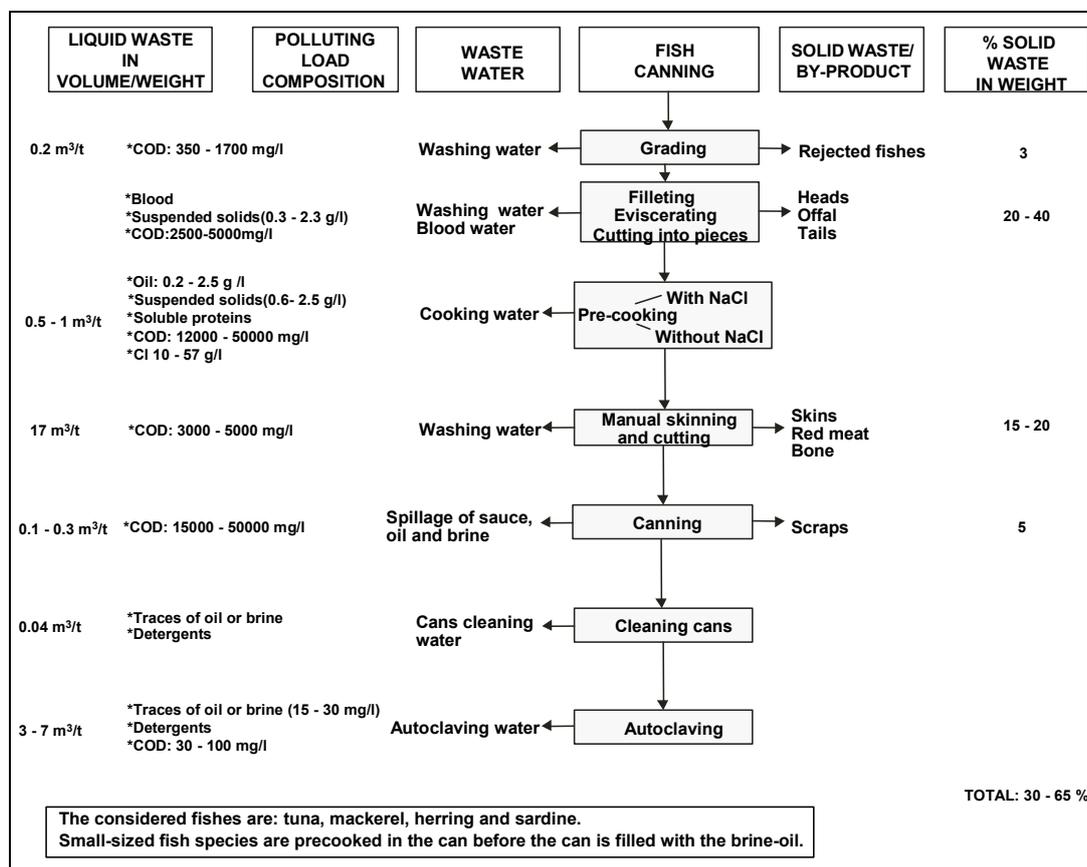


Figure 3.3: Consumption and emission levels of the process steps in fish canning [134, AWARENET, 2002]

Solid by-products of the filleting, curing, salting and the smoking of fish have similar uses as mentioned above for the canning of fish. Ash from shavings is generally disposed of with municipal solid waste. Figure 3.4 shows the consumption and emission levels of the process steps in filleting and preserving fish.

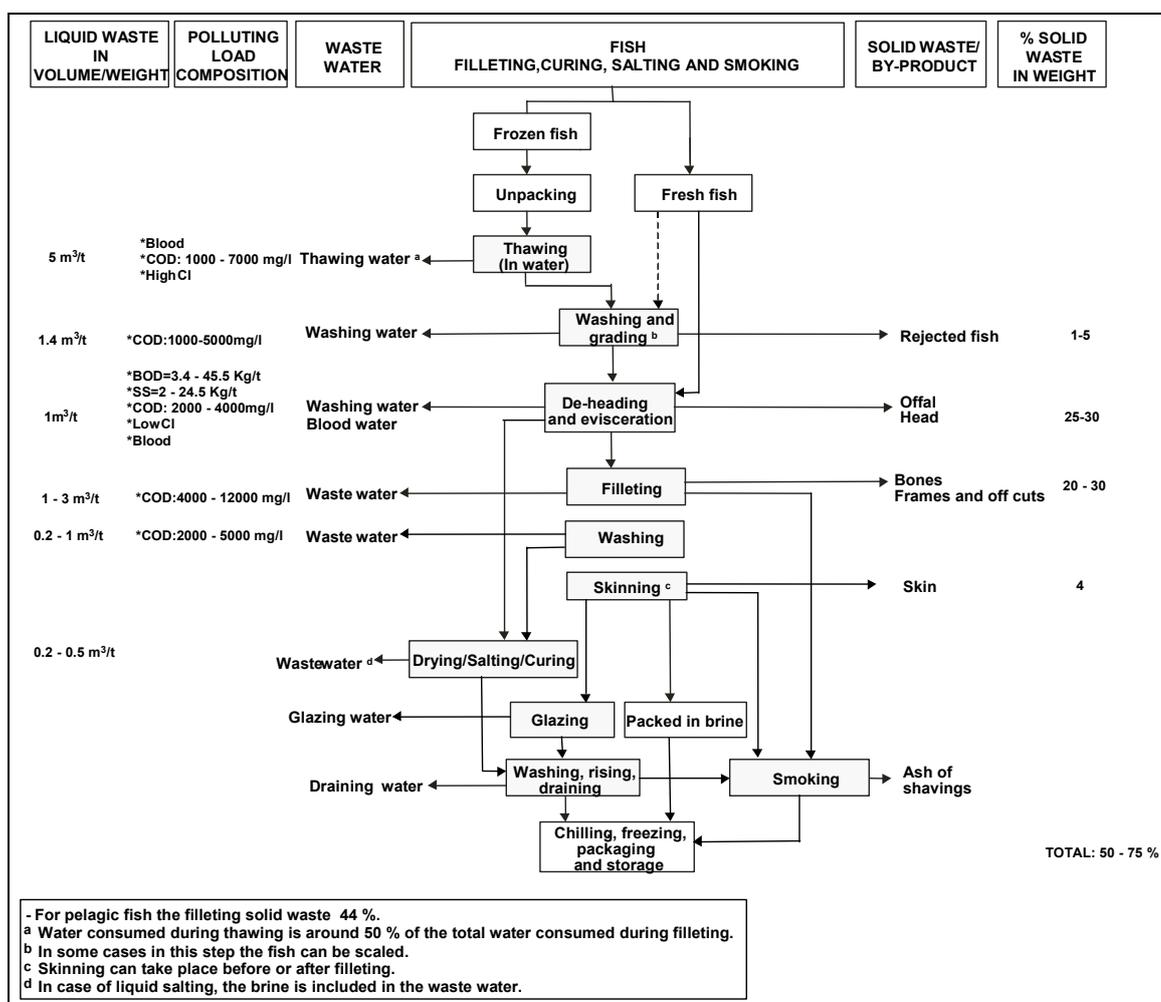


Figure 3.4: Consumption and emission levels of the process steps in filleting and preserving fish [134, AWARENET, 2002]

The main crustaceans processed and consumed in Europe comprise shrimps, prawns, lobsters, crayfish crabs and crabs. The main processing steps together with consumption and emission levels are presented in Figure 3.5.

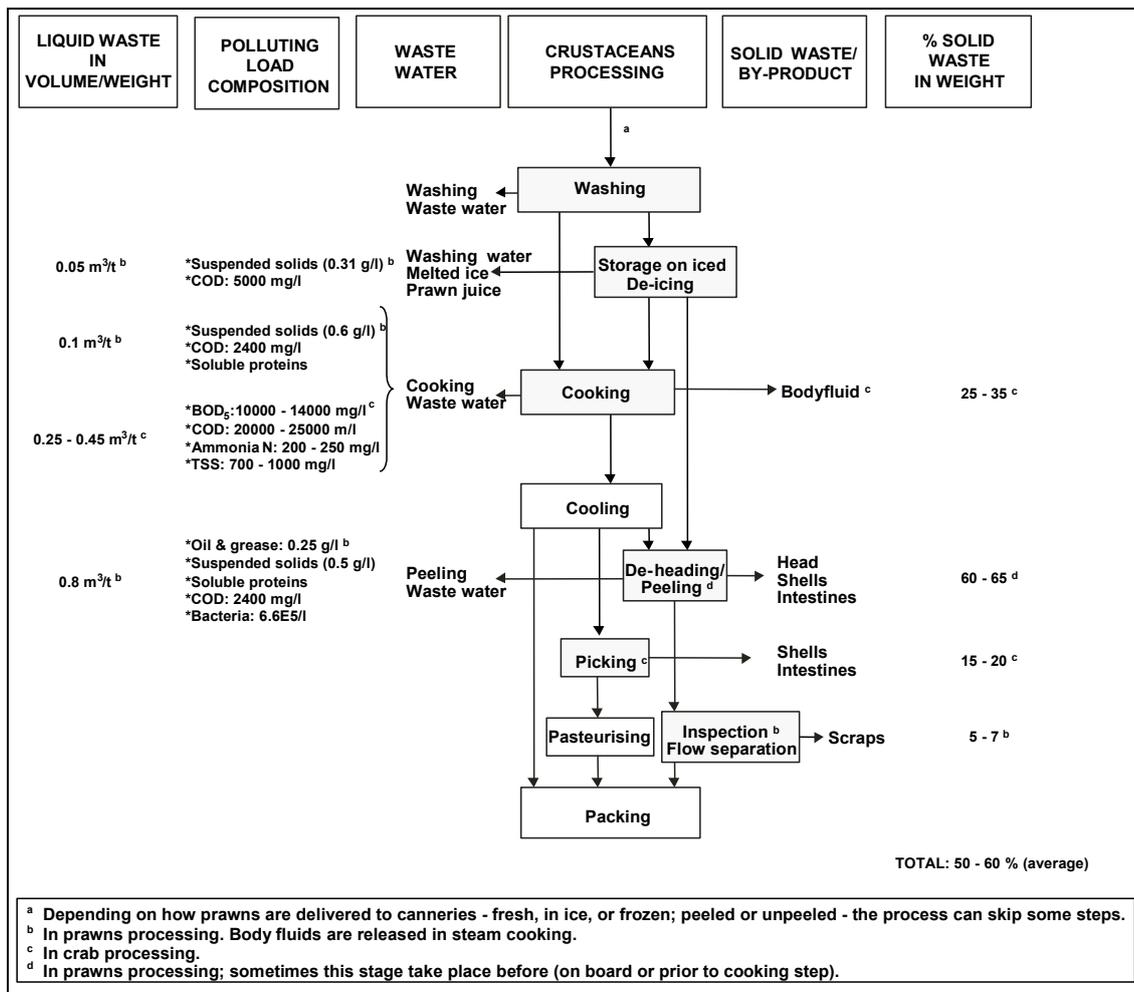


Figure 3.5: Consumption and emission levels of the process steps in crustaceans processing [134, AWARENET, 2002]

Sand and shell particles generated during the shell removal and washing steps of mollusc processing are used in the production of chemicals such as plastics and paints, construction materials and fertilisers. Fluid lost from the fish, e.g. clam juice, may be used in foodstuffs. Figure 3.6 shows the consumption and emission levels of the process steps in mollusc processing.

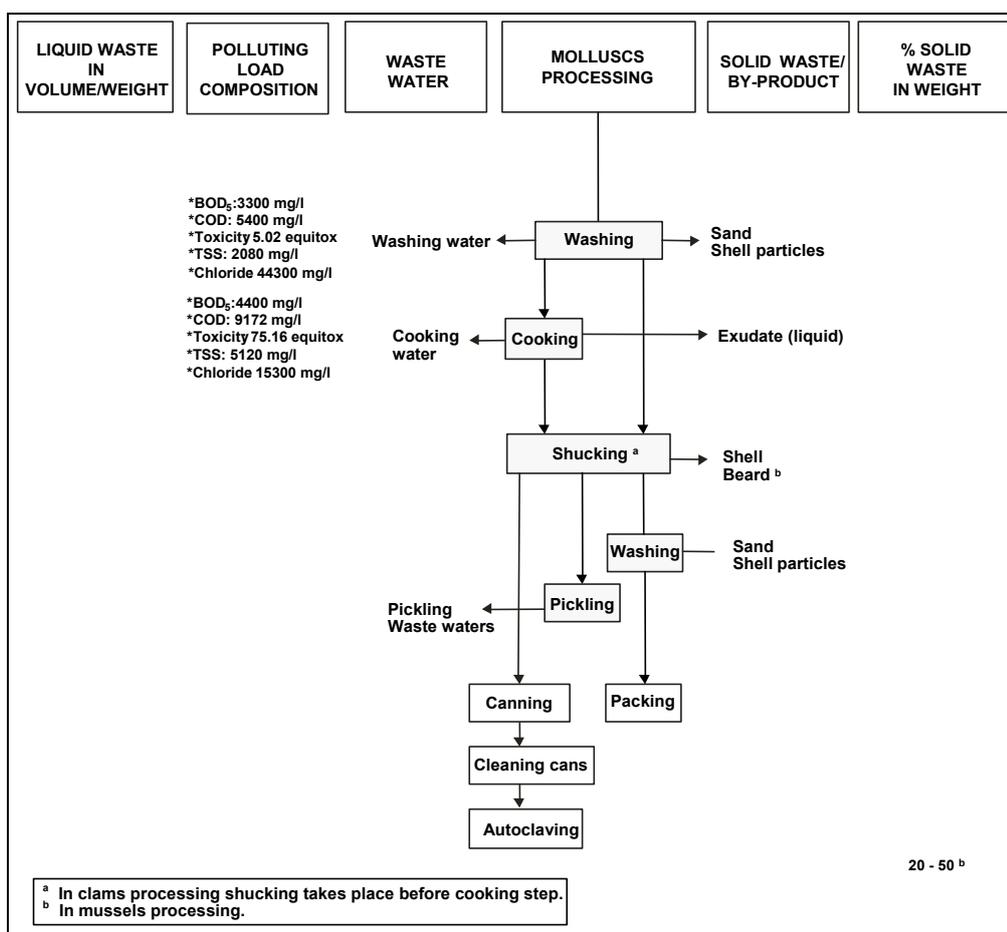


Figure 3.6: Consumption and emission levels of the process steps in mollusc processing [134, AWARENET, 2002]

### 3.3.2.4 Energy

The consumption of energy depends on the installation, the equipment and the fish manufacturing processes that take place. Processes, e.g. canning, that involve heating, cooling, production of ice, drying, evaporation and oil production consume more energy than those that do not, e.g. filleting, where energy consumption is low. On average, filleting consumes 65 - 87 kWh/t of fish and canning consumes 150 – 190 kWh/t of fish.

## 3.3.3 Fruit and vegetables

### 3.3.3.1 Water consumption

Water is used mainly during washing. It is also used during peeling and blanching. The fruit and vegetable canning industry in Greece consumes 7 – 15 m<sup>3</sup> water per tonne of product. Table 3.19 shows water consumption levels reported by, and achieved in, fruit and vegetable installations. Water consumption levels reported for some processes in the fruit and vegetable sector are shown in Table 3.20.

| Product category  | Water consumption (m <sup>3</sup> /t product) |
|-------------------|---|
| Canned fruit      | 2.5 – 4.0                                     |
| Canned vegetables | 3.5 – 6.0                                     |
| Frozen vegetables | 5.0 – 8.5                                     |
| Fruit juices      | 6.5   |
| Jams              | 6.0   |
| Baby food         | 6.0 – 9.0                                     |

**Table 3.19: Water consumption levels achieved in fruit and vegetable installations [140, World Bank (IBRD), et al., 1998]**

| Type of processing  | Water consumption (m <sup>3</sup> /t finished product) |
|---|--|
| Deep frozen vegetables  | 2.5 – 5.0  |
| non-peeled products, e.g. leeks, onions, aubergines, cabbage, blanched celery, rhubarb and courgettes | 2.6  |
| beans, peas, cauliflower, sprouts and flageolets  | 3.0  |
| blanched leaf vegetables, e.g. spinach  | 5.1  |
| peeled products, e.g. carrots, celery and potatoes  | 3.8  |
| Preserved vegetables (range)  | 7 – 11   |
| well managed  | 5.9  |
| Potato processing (range)   | 4.5 – 9.0  |
| well managed  | 5.1  |
| Potato peeling company (well managed)   | 2.4  |

**Table 3.20: Water consumption for some processes in the fruit and vegetable sector [5, Derden A Vercaemst P and Dijkmans R, 1999, 134, AWARENET, 2002]**

Tomatoes are one of the most processed raw materials. Italy is the second largest producer in the world after the US, and the largest exporter of tomato products. Reported figures for water and energy consumption together with waste water and solid waste production in the different processing steps for canned peeled tomatoes and tomato juice are summarised in Table 3.21 and Table 3.22.

| Canned peeled tomatoes (whole and cut) |  |                        |                            |                          |                   |                  |
|--|--|------------------------|----------------------------|--------------------------|-------------------|------------------|
| Unit operation                         |  | Water consumption      | Waste water load           | By-products/solid wastes | Electrical energy | Thermal energy   |
| No.                                    | Description  | (m <sup>3</sup> /t)    | (kg COD/t)                 | (kg/t)                   | (kWh/t)           | (kg steam/t)     |
| A.1                                    | Materials handling and storage   | 0.2                    | 1.5                        | 10 – 15                  | 1                 |                  |
| A.2                                    | Sorting/screening, grading, dehulling, destemming/destalking and trimming  | 1                      | 0.1                        | 0.2                      | 1.5               |                  |
| A.3                                    | Peeling (refining)   | 0.5 – 2                | 3 – 5                      | 25 – 30                  | 2.5               | 100              |
| A.4                                    | Washing  | 2                      | 2                          | 0.2                      | 0.5               |                  |
| B.1                                    | Cutting, slicing, chopping, mincing, pulping and pressing  |                        | 1                          |                          |                   |                  |
| B.2                                    | Mixing/blending, homogenisation and conching   |                        |                            |                          |                   |                  |
| C.5                                    | Filtration   |                        | 1                          |                          |                   |                  |
| E.2                                    | Blanching  |                        | 0.5                        |                          | 4 - 5             | 60               |
| E.8                                    | Pasteurisation, sterilisation and UHT  | 15 – 25 <sup>(1)</sup> |                            |                          | 2                 | 450 – 500        |
|  | Cans and bottles   |                        |                            |                          |                   | 200 – 300        |
| F.1                                    | Evaporation (for juice)  | 10 – 12 <sup>(1)</sup> |                            |                          | 7 – 8             | 150 – 200        |
| H.1                                    | Packing and filling  |                        |                            | 0.5                      | 1.5               |                  |
| U.1                                    | Cleaning and disinfection  | 1.5                    | 1                          | 0.2 – 1                  |                   |                  |
| U.4                                    | Vacuum generation  | 0.5                    |                            |                          | 1 - 2             |                  |
|  | <b>Overall totals of typical installations</b><br>(all unit operations are not undertaken at each installation, so the totals are not the sum of the levels for each unit operation) | <b>35 – 40</b>         | <b>7 – 10</b>              | <b>25 – 35</b>           | <b>19 – 24</b>    | <b>750 – 850</b> |
|  |  |                        | <b>6 – 8<sup>(2)</sup></b> |                          |                   |                  |

<sup>(1)</sup>Not discharged, but recycled  
<sup>(2)</sup>Waste water – m<sup>3</sup>/t

**Table 3.21: Consumption and emission levels for canning tomatoes [89, Italian contribution, 2001, 184, Italy, 2003]**

| Tomato juice, puree and paste (28 – 30 °Brix puree <sup>(1)</sup> ) |  |                                |                              |                          |                   |                    |
|---|--|--------------------------------|------------------------------|--------------------------|-------------------|--------------------|
| Unit operation  |  | Water consumption              | Waste water load             | By-products/solid wastes | Electrical energy | Thermal energy     |
| No.   | Description  | (m <sup>3</sup> /t)            | (kg COD/t)                   | (kg/t)                   | (kWh/t)           | (kg steam/t)       |
| A.1   | Materials handling and storage   | 5                              | 6                            | 12                       | 0.4               |                    |
| A.2   | Sorting/screening, grading, dehulling, destemming/destalking and trimming  | 10                             | 2                            |                          | 1.5               |                    |
| A.3   | Peeling (refining)   |                                |                              | 150 – 200                | 8 – 12            |                    |
| A.4   | Washing  | 15                             | 5                            |                          |                   |                    |
| B.1   | Cutting, slicing, chopping, mincing, pulping and pressing  |                                |                              |                          | 2.5               |                    |
| B.2   | Mixing/blending, homogenisation and conching   |                                |                              |                          |                   |                    |
| E.2   | Blanching  |                                |                              |                          | 15 – 25           | 700 – 900          |
| E.8   | Pasteurisation, sterilisation and UHT  |                                |                              |                          | 0.5               | 60 – 80            |
| F.1   | Evaporation (liquid to liquid)   | 100 – 150 <sup>(2)</sup>       |                              |                          | 60 – 80           | 1500 – 1800        |
| F.2   | Drying (liquid to solid)   |                                |                              |                          |                   |                    |
| H.1   | Packing and filling  |                                |                              | 1.5                      | 3.5               | 10                 |
| U.1   | Cleaning and disinfection  |                                | 1                            |                          |                   |                    |
| U.4   | Vacuum generation  | 1                              |                              |                          | 4 - 5             |                    |
|   | <b>Overall totals of typical installations</b><br>(all unit operations are not undertaken at each installation, so the totals are not the sum of the levels for each unit operation) | <b>130 – 180<sup>(2)</sup></b> | <b>10 – 12</b>               | <b>160 – 210</b>         | <b>90 – 125</b>   | <b>2300 – 2800</b> |
|   |  |                                | <b>60 – 80<sup>(2)</sup></b> |                          |                   |                    |

<sup>(1)</sup> All figures are referred to 1 t of 28 – 30 °Brix tomato puree. Conversion coefficients for other final products: 7 – 12 °Brix puree – multiply by 0.3; 20 – 22 °Brix puree – multiply by 0.7, 36 – 40 °Brix puree – multiply by 1.3  
<sup>(2)</sup> Without cooling towers

**Table 3.22: Consumption and emission levels for manufacturing of tomato juice, puree and paste [89, Italian contribution, 2001, 184, Italy, 2003]**

### 3.3.3.2 Waste water

Waste water characteristics are affected by various factors. These include the raw material being processed, seasonal and source variations, unit operations, production patterns and operator practice. Table 3.23 shows data reported for canning fruits and vegetables in the US.

| Parameter   | Fruit | Vegetables |
|---|-------|------------|
| Waste water volume (m <sup>3</sup> /t raw material) | 10.86 | 22.91      |
| BOD <sub>5</sub> (kg/t raw material)                | 11.8  | 13.0       |
| TSS (kg/t raw material)                             | 2.2   | 6.6        |

**Table 3.23: Average waste water and water pollution generated in the US canning industry in 1975 [74, Greek Ministry for the Environment, 2001]**

Typically, waste water is high in SS, sugars and starches. Residual pesticides that are difficult to degrade during waste water treatment may be a concern, especially with produce from countries with less stringent controls on pesticide use.

Reported levels of BOD and TSS in the waste water arising from the processing of various fruits and vegetables, are shown in Table 3.24 and Table 3.25.

| BOD <500 mg/l         |             | BOD 500 – 1000 mg/l      |            | BOD 1000 – 2000 mg/l |              |
|-----------------------|-------------|--------------------------|------------|----------------------|--------------|
| Product               | TSS mg/l    | Product                  | TSS mg/l   | Product              | TSS mg/l     |
| Citrus                | 130         | Apple juice              | 104        | Frozen potatoes      | 1716         |
| Asparagus             | 43 – 114    | Strawberries             | 96 – 210   | Dried potatoes       | 981          |
| Broccoli              | 100 – 455   | Baby foods               | 101 – 533  | Apricots             | 33 – 387     |
| Brussel sprouts       | 29 – 1680   | Peeled tomatoes          | 280 – 1280 | Mushrooms            | 33 – 467     |
| Cauliflowers          | 18 – 113    | Tomato products          | 512 – 1180 | Peaches              | 164 – 1020   |
| Dehydrated vegetables | 168 – 778   |                          |            | Plums                | 60 – 187     |
| Leafy greens          | 19 – 419    |                          |            |                      |              |
| BOD 2000 – 3000 mg/l  |             | BOD 3000 – 5000 mg/l     |            | BOD >5000 mg/l       |              |
| Product               | TSS mg/l    | Product                  | TSS mg/l   | Product              | TSS mg/l     |
| Carrots               | 262 – 1540  | Dried fruit              | 8 – 568    | Beetroots            | 367 – 4330   |
| Grape juice           | 216 – 228   | Jams, jellies, preserves | 404 – 711  | Whole potatoes       | 1660 – 24300 |
| Peas                  | 79 – 673    | Pears                    | 84 – 702   | Sweetcorn            | 131 – 2440   |
| Potato crisps         | 1450 – 3910 |                          |            |                      |              |

**Table 3.24: BOD and TSS concentrations in waste water from fruit and vegetable processing [140, World Bank (IBRD), et al., 1998]**

| Type of operation  | SS (mg/l)         | COD (mg/l) | BOD <sub>5</sub> (mg/l) | N <sub>tot</sub> (mg/l) | P <sub>tot</sub> (mg/l) |
|--|-------------------|------------|-------------------------|-------------------------|-------------------------|
| Vegetables, frozen vegetables, preserves, fruit and vegetable juices | 700               | 5000       | 3000                    | 150                     | 30                      |
| Potato processing  | 700               | 10000      | 3000                    | 150                     | 200                     |
| Potato peeling   | 1100              | 6000       | 2500                    | 200                     | 30                      |
| Fruit and vegetable juices <sup>1</sup>                              |                   |            |                         |                         |                         |
| Apples   | 33 <sup>2</sup>   | 5500       | 2500                    | 26.5                    | 21                      |
| Apples (without pressing)  | 16.5 <sup>2</sup> | 5100       | 2500                    | 27                      | 23                      |
| Sour cherries  | 9 <sup>2</sup>    | 4000       | 2300                    | 15                      |                         |
| Blackcurrants  | 24 <sup>2</sup>   | 4900       | 2600                    | 13.5                    | 12.5                    |
| Blackcurrants without pressing                                       | 21 <sup>2</sup>   | 4600       | 2100                    | –                       | 9                       |
| Carrots  | 24 <sup>2</sup>   | 8600       | 2700                    |                         |                         |
| <sup>1</sup> ) Rounded average figures                               |                   |            |                         |                         |                         |
| <sup>2</sup> ) Settleable solids after two hours, ml/l               |                   |            |                         |                         |                         |

**Table 3.25: Waste water characteristics from some fruit and vegetable processing [5, Derden A Vercaemst P and Dijkmans R, 1999, 65, Germany, 2002]**

Specific waste water generation and pollution loads are presented in the next two tables. Table 3.26 shows reported loads per unit production that can be achieved by implementing pollution reduction measures, such as procuring clean raw fruit and vegetables, and the use of countercurrent systems for washing and recycling process water, although the specific techniques used for each example and the unit of product are not identified. Table 3.27 shows the waste water volume and water pollution per unit of product generated in the processing of some fruit.

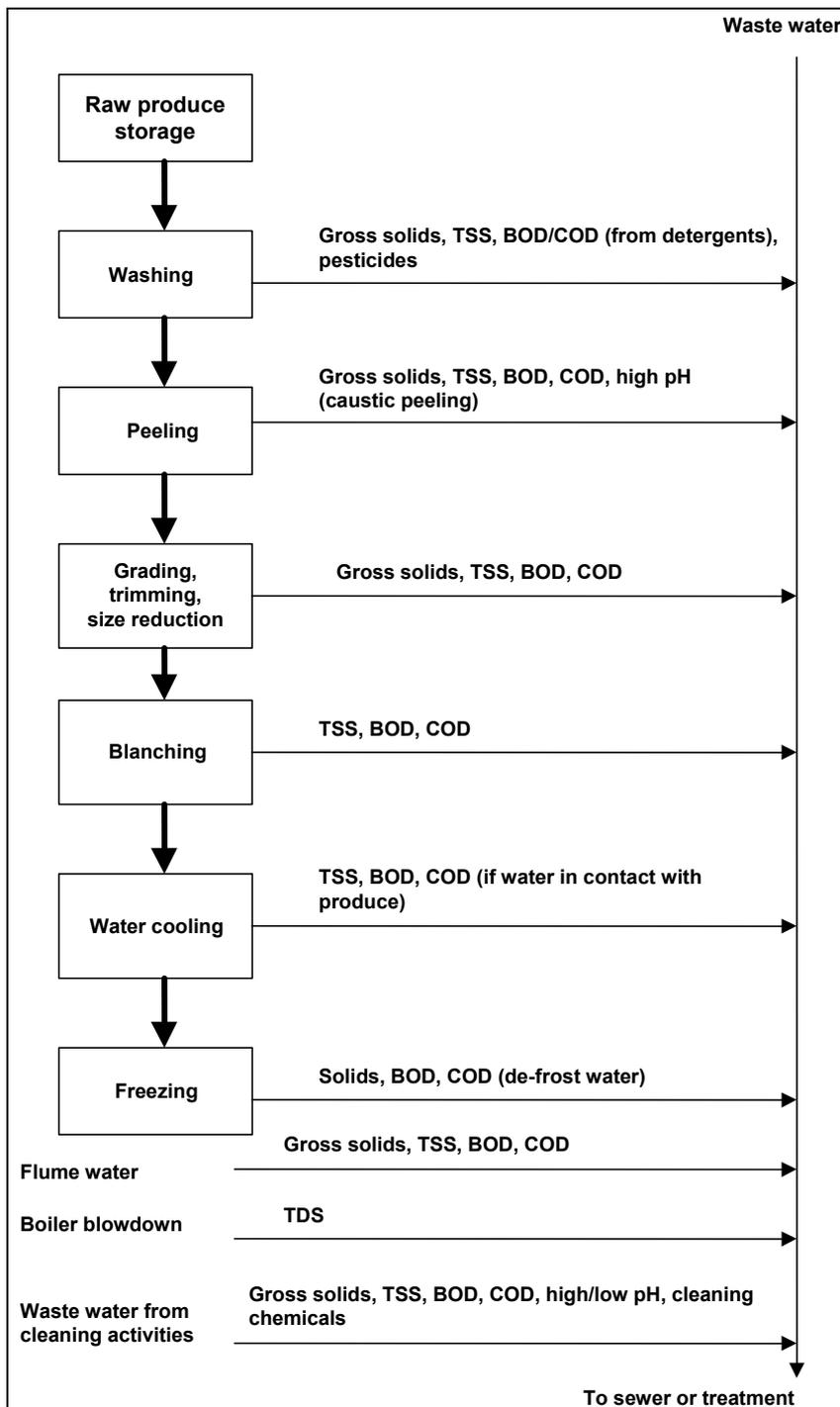
| Product   | Waste water volume<br>(m <sup>3</sup> /U) | BOD <sub>5</sub><br>(kg/U) | TSS<br>(kg/U) |
|---|---|----------------------------|---------------|
| Asparagus   | 69.0                                      | 2.1                        | 3.4           |
| Broccoli  | 11.0                                      | 9.8                        | 5.6           |
| Brussels sprouts  | 36.0                                      | 3.4                        | 11.0          |
| Carrots   | 12.0                                      | 20.0                       | 12.0          |
| Cauliflowers  | 89.0                                      | 5.2                        | 2.7           |
| Maize   |   |                            |               |
| Canned  | 4.5                                       | 14.0                       | 6.7           |
| Frozen  | 13.0                                      | 20.0                       | 5.6           |
| Dehydrated onions and garlic  | 20.0                                      | 6.5                        | 5.9           |
| Dehydrated vegetables   | 22.0                                      | 7.9                        | 5.6           |
| Dry beans   | 18.0                                      | 15.0                       | 4.4           |
| Lima beans  | 27.0                                      | 14.0                       | 10.0          |
| Mushrooms   | 22.0                                      | 8.7                        | 4.8           |
| Onions, canned  | 23.0                                      | 23.0                       | 9.3           |
| Peas  |   |                            |               |
| Canned  | 20.0                                      | 22.0                       | 5.4           |
| Frozen  | 15.0                                      | 18.0                       | 4.9           |
| Pickles   |   |                            |               |
| Fresh packed  | 8.5                                       | 9.5                        | 1.9           |
| Process packed  | 9.6                                       | 18.0                       | 3.3           |
| Salting stations  | 1.1                                       | 8.0                        | 0.4           |
| Pimentos  | 29.0                                      | 27.0                       | 2.9           |
| Potatoes  |   |                            |               |
| All products  | 10.0                                      | 18.0                       | 16.0          |
| Frozen products   | 11.0                                      | 23.0                       | 19.0          |
| Dehydrated products   | 8.8                                       | 11.0                       | 8.6           |
| Cabbage   |   |                            |               |
| Canned  | 3.5                                       | 3.5                        | 0.6           |
| Cut   | 0.4                                       | 1.2                        | 0.2           |
| Snap beans  |   |                            |               |
| Canned  | 15.0                                      | 3.1                        | 2.0           |
| Frozen  | 20.0                                      | 6.0                        | 3.0           |
| Spinach   |   |                            |               |
| Canned  | 38.0                                      | 8.2                        | 6.5           |
| Frozen  | 29.0                                      | 4.8                        | 2.0           |
| Squash  | 5.6                                       | 17.0                       | 2.3           |
| Sweet potatoes  | 4.1                                       | 30.0                       | 12.0          |
| Tomatoes  |   |                            |               |
| Peeled  | 8.9                                       | 4.1                        | 6.1           |
| Products  | 4.7                                       | 1.3                        | 2.7           |
| Unit of production (U) is not defined in [140, World Bank (IBRD), et al., 1998] |   |                            |               |

**Table 3.26: Waste water volume and water pollution per unit of product generated in the processing of some vegetables**  
[140, World Bank (IBRD), et al., 1998]

| Product   | Waste volume<br>(m <sup>3</sup> /U) | BOD <sub>5</sub><br>(kg/U) | TSS<br>(kg/U) |
|---|-------------------------------------|----------------------------|---------------|
| Apricots  | 29.0                                | 15.0                       | 4.3           |
| Apples  |                                     |                            |               |
| All products  | 3.7                                 | 5.0                        | 0.5           |
| All except juice  | 5.4                                 | 6.4                        | 0.8           |
| Juice   | 2.9                                 | 2.0                        | 0.3           |
| Cranberries   | 5.8                                 | 2.8                        | 0.6           |
| Citrus  | 10.0                                | 3.2                        | 1.3           |
| Sweet cherries  | 7.8                                 | 9.6                        | 0.6           |
| Sour cherries   | 12.0                                | 17.0                       | 1.0           |
| Bing cherries   | 20.0                                | 22.0                       | 1.4           |
| Cranberries   | 12.0                                | 10.0                       | 1.4           |
| Dried fruit   | 13.0                                | 12.0                       | 1.9           |
| Grapefruit  |                                     |                            |               |
| Canned  | 72.0                                | 11.0                       | 1.2           |
| Pressed   | 1.6                                 | 1.9                        | 0.4           |
| Peaches   |                                     |                            |               |
| Canned  | 13.0                                | 14.0                       | 2.3           |
| Frozen  | 5.4                                 | 12.0                       | 1.8           |
| Pears   | 12.0                                | 21.0                       | 3.2           |
| Pineapples  | 13.0                                | 10.0                       | 2.7           |
| Plums   | 5.0                                 | 4.1                        | 0.3           |
| Raisins   | 2.8                                 | 6.0                        | 1.6           |
| Strawberries  | 13.0                                | 5.3                        | 1.4           |
| Unit of production (U) is not defined in [140, World Bank (IBRD), et al., 1998] |                                     |                            |               |

**Table 3.27: Waste water volume and water pollution per unit of product generated in the processing of some fruit**  
[140, World Bank (IBRD), et al., 1998]

Up to this point in this section, general data on water pollution from fruit and vegetable processing have been reported. In the following paragraphs, there is a breakdown of all unit operations that generate waste water. A reported typical process showing the waste water which arises from the major unit operations is shown in Figure 3.7.



**Figure 3.7: Waste water produced in fruit and vegetable processing**  
[13, Environment Agency of England and Wales, 2000]

The incoming produce is washed in chlorinated water to remove residual soil, stones and other debris and to reduce the microbial population. Large volumes of chlorinated water are required, especially for root vegetables which carry a lot of earth, and leafy vegetables which have a large surface area. Mechanical or air flotation techniques are used to aid soil removal and reduce the quantity of water used. Some recirculation or re-use of water from other operations is common. Waste water from pre-washing mainly contains field debris and soil particles with small fragments of the fruit or vegetables. If detergents are used to increase cleaning efficiency, they contribute to the COD of the waste water.

Most processes involve some type of grading, trimming and size reduction. Sometimes density graders containing brines of different strength are used. Discharge of significant quantities of brine can adversely affect any biological WWTP. Washing of the produce after these operations creates waste water containing soluble starch, sugars and acids. The use of water fluming to convey both the product and waste material causes additional leaching of these substances. Waste water from citrus fruit processing also contains pectic substances that can interfere with the sedimentation of SS.

All lines, equipment and process areas that are not in designated dry areas require wet cleaning, which generates waste water contaminated with raw material, product and cleaning chemicals. There are generally fewer requirements for aggressive chemicals in this sector than in others, unless oil or fat is used in processing.

### 3.3.3.3 Solid output

Large amounts of solid wastes are produced. These are organic materials, including fruit and vegetables discarded during selection, and those from processes such as peeling or coring. These typically have a high nutritional value and can be used as animal feed. Undesired materials discarded from the first processing steps include soil and extraneous plant material, spoiled food stocks, and some trimmings, peels, pits, seeds and pulp.

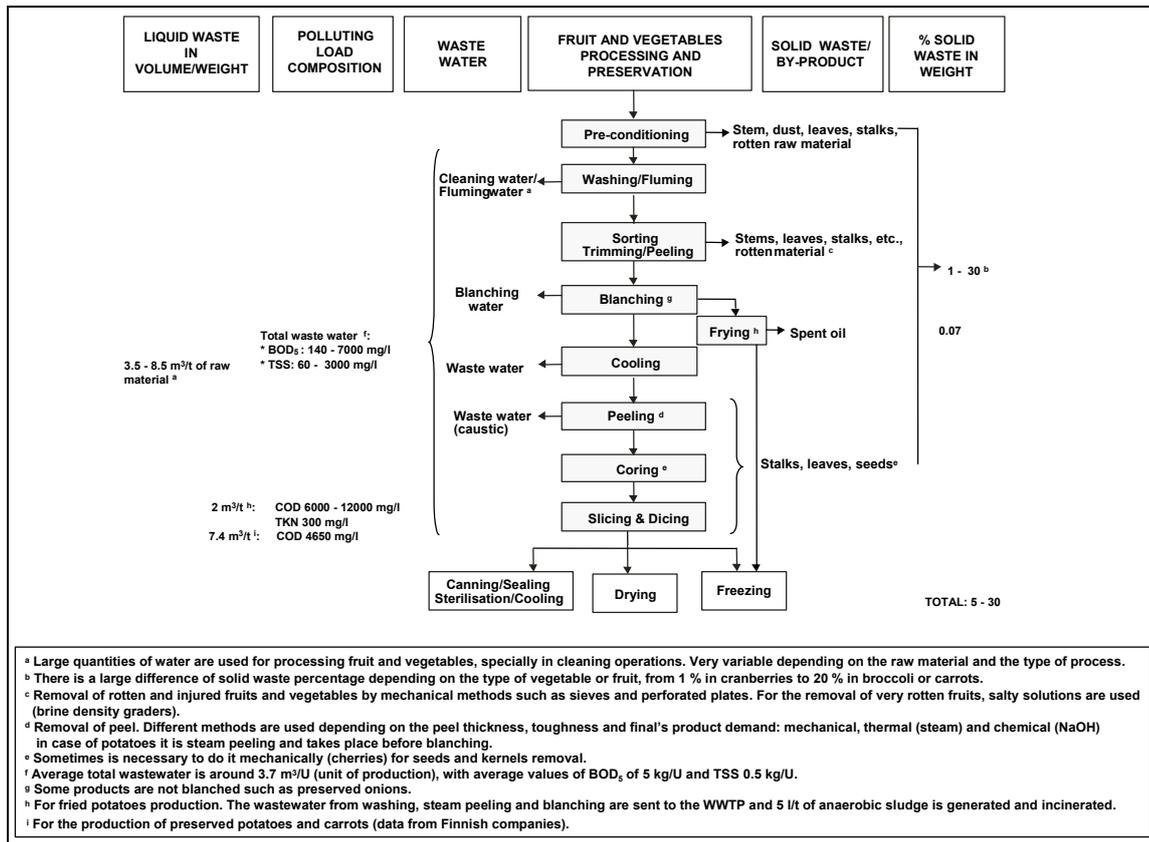
When caustic agents are used for peeling fruit and soft vegetables, a highly alkaline or salty solid waste is produced. High moisture content solid wastes can be generated by wet cleaning and re-use operations in which the dissolved solids or SS are concentrated and separated from the waste water.

Up to 50 % of fruit and typically 10 to 30 % of raw vegetable materials are wasted during processing. Part of the waste goes to the waste water and significant amounts of solid wastes are also generated. Some reported figures are shown in Table 3.28.

| Raw material processed | Solid waste produced per tonne of product (kg) |
|------------------------|--|
| Maize                  | 40   |
| Peas                   | 40   |
| Potatoes               | 40   |
| Strawberries           | 60   |
| Apples                 | 90   |
| All vegetables         | 130  |
| Peaches                | 180  |
| Broccoli               | 200  |
| Carrots                | 200  |
| Frozen peaches*        | 200  |

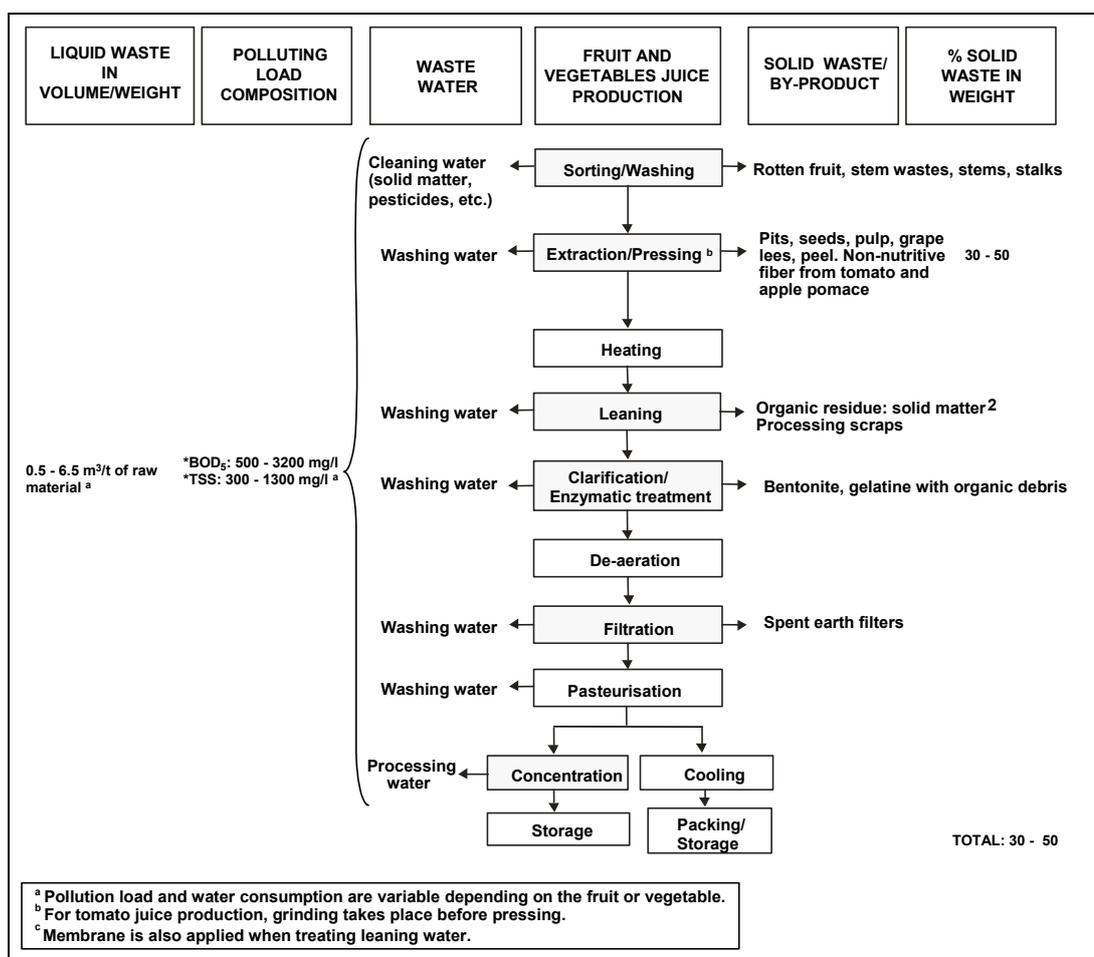
**Table 3.28: Solid waste produced during fruit and vegetable processing**  
[140, World Bank (IBRD), et al., 1998]

The reported types and amount of wastes produced in processing and preservation of fruit and vegetables are shown in Figure 3.8.



**Figure 3.8: Type and amount of wastes produced in fruit and vegetable processing and preservation [134, AWARENET, 2002]**

Some reported figures for producing fruit and vegetable juices are shown in Figure 3.9.



**Figure 3.9: Type and amount of wastes produced in fruit and vegetable juice manufacturing [134, AWARENET, 2002]**

If fruit and vegetables are treated with enzymes during juice manufacturing, less waste is produced. Table 3.29 shows the effects of apple and tomato processing in Hungary.

| Raw materials | Type of pretreatment | Amount of waste (%) |
|---------------|----------------------|---------------------|
| Apple         | With enzyme          | 8 – 18              |
|               | Without enzyme       | 10 – 25             |
| Tomato        | With enzyme          | 2 – 6               |
|               | Without enzyme       | 4 – 8               |

**Table 3.29: Fruit and vegetable wastes in juice manufacturing in Hungary [134, AWARENET, 2002]**

Solid wastes are normally used for the production of animal feed and organic fertilisers. They may also be used for producing food or other marketable products, or disposed of in waste water or to land. Possible re-use and disposal routes for the different solid wastes produced are as follows:

- non-nutritive fibre from apple pomace, dried citrus peel and lecithin from soybeans, may be used for the production of foods such as fermented foods, drinks, oils and proteins, or for the development of biopolymers for elaboration of biodegradable packing and construction material. Pectin is extracted from apples. Citrus is extracted during juice production
- citrus wastes, grape lees, grapes and potato processing wastes, may be used for biosynthesis of natural chemicals such as furfural, xylitol, alcohol, organic acids and polysaccharides, and pharmaceuticals such as hycogenin, antibiotics and vitamins. This option is growing as more opportunities are identified

- production of animal feed from sugar beet pulp, apple and tomato pomace and citrus pulp pellets, without or after treatment (physical, chemical, microbial, ensilage, production of microbial biomass). This use is limited by several factors, including shipping, putrefaction during storage and transport, and the presence of undesirable constituents such as alkalis or salt. Water content is the major contributor to shipping costs and to some extent to the putrefaction rates. Putrefaction reduces the shelf-life and value of the solid wastes and limits its use as animal feed
- peach and olive pits, rice hulls and straw, may be burnt directly, or converted to produce biogas or alcohol. Incineration is a viable option for solid wastes with a relatively low (<10 %) water content. Catalytic gasification or pyrolysis may also be applied
- composting and land application of organic waste is limited because of odour and possible soil contamination by leaching organics and salts.

Within the unit operations used in the fruit and vegetables sector, peeling is one of the major solid output and waste water producers.

Steam peeling is generally used for large quantities of potatoes, carrots and other tubers. Pre-processing includes the washing and the separation of mud and stones. This solid waste has no value for bioconversion. The waste produced in peeling has solids, mainly peel, which are separated by sedimentation from the aqueous phase, dried and may be composted. They may be further treated to recover minerals, fibre and phenolics. The aqueous phase goes for waste water treatment together with waste water from other processes. Its pollution, before discharge to MWWTP, expressed in COD is about 4000 mg/l. Soluble vitamins, starch, fibre and tissue fluid may be recovered from this waste water.

Mechanical peeling is used for small quantities of potatoes, carrots, apples, pears, etc. or when vegetables are used for catering or in institutional kitchens. The peeling is often performed outside the main processor. There are numerous peeling companies with varying capacity and equipment. The unit operations are basically the same as in steam peeling. The processing starts with the separation of mud and stones similar to the step for the steam peeling process.

The peeling consists of three consecutive steps: mechanical pre-peeling, using, e.g. carborundum; knife peeling and then washing. Waste water is produced in all three steps. After sedimentation, the aqueous phase goes for waste water treatment. Its pollution expressed in COD is about 5000 mg/l. The separated solid phase is normally composted. Vitamins, starch, fibre and minerals may be recovered.

Knife peeling produces a similar output as steam peeling and it can be used similarly, either directly as animal feed or for recovery of its components. About 60 % of the total organic solid waste produced comes from pre-peeling, by abrasion peeling and the rest is from knife peeling. After cutting, defective pieces which are, e.g. too dark or too small, are separated and used as animal feed. However, especially in carrot processing, several valuable substances such as vitamin C, fibre, phenolic compounds and carotenoids, can be recovered from this by-product. The next step is rinsing, and in the case of potato processing, this is usually combined with the addition of browning inhibitors or sulphites before transporting the peeled product to the main processing facility.

Data comparing outputs from processes using either steam peeling or a combination of abrasion peeling and knife peeling is shown in Abbildung 4.50 and Abbildung 4.51.

### 3.3.3.4 Energy

Processes involving heating, cooling, drying, evaporation, sterilisation, pasteurisation and blanching consume significant energy.

Almost every process step requires electricity. For steam production, natural gas boilers can be used. The frozen vegetable sector is a large consumer of electricity and natural gas. Deep freezing is the process which uses the most electricity.

During deep freezing, cooling to a very low temperature level, i.e. -30 to -40 °C, is necessary. During this process, energy is consumed at a rate of 80 to 280 kWh<sub>e</sub>/t of frozen vegetables. Other processes, e.g. washing, require less electrical energy, a maximum of 28 kWh<sub>e</sub>/t of frozen product.

Deep freezing carrots consumes ±8 kWh<sub>e</sub>/t and freezing salsifies consumes ± 20 kWh<sub>e</sub>/t and these require a lot of electrical energy for sorting. Washing spinach for deep freezing consumes ± 4 kWh<sub>e</sub>/t and is electricity intensive. The mechanical processing of frozen beans and salsifies consumes ± 6 kWh<sub>e</sub>/t and ± 9 kWh<sub>e</sub>/t respectively, i.e. much more electricity compared with other vegetables.

The electricity consumption of the belt blancher with air cooling, which produces 7 to 30 kWh<sub>e</sub>/t of frozen product, is significantly higher than that of the belt blancher with water cooling, which produces 2 to 9 kWh<sub>e</sub>/t of frozen product, or the drum blancher with countercurrent water cooling, which produces 1 to 2.6 kWh<sub>e</sub>/t of frozen product. Spinach requires most electricity for intermediate processes such as packing or making of portions

Steam is used for peeling and blanching. Steam peeling uses approximately five times more steam than caustic peeling. Belt blanching with water cooling consumes approximately half the energy of belt blanching with air cooling or drum blanching with countercurrent water cooling. For storage, electricity consumption is between 20 and 65 kWh<sub>e</sub>/m<sup>3</sup> of storage space/year.

### 3.3.3.5 Data for some fruit and vegetable products

#### 3.3.3.5.1 Fresh-pack

Fresh-pack fruit and vegetables require minimal processing. Water consumption is mainly for produce washing, transport flumes and line cleaning. Processing installations are often close to growing areas, creating opportunities for the use of waste water in irrigation. Some fresh-pack vegetables require peeling.

#### 3.3.3.5.2 Preserved fruit and vegetables

Fruit and vegetables that are to be preserved undergo further processing. The most common types are discussed below.

Many vegetables and some fruits require **peeling**, which can be a major source of BOD and TSS and represent a substantial proportion of the total waste water volume. Peeling is usually followed by washing.

Conventional steam peeling uses large quantities of water and produces waste water with high levels of product residue. At potato processing installations, the peelings can contribute up to 80 % of the total BOD. In fruit processing, peeling waste water can account for as much as 10 % of the total waste water flow and 60 % of the BOD. Water cooling in steam peeling increases water consumption.

Caustic peeling causes higher solubilisation of material and consequently a higher COD, BOD and SS load than mechanical peeling, which is a combination of knife and abrasion peeling. Furthermore, the use of caustic in peeling may lead to pH fluctuations in the waste water. Dry caustic peeling tends to have a lower caustic consumption than wet methods and can greatly reduce the volume and strength of the waste water from this operation and allows for the collection of peel as a pumpable slurry.

**Blanching** is used in most vegetables destined for canning, freezing or drying. Typically, it is carried out using hot water or steam. If the produce is to be frozen, blanching is followed by water or air cooling.

Both water and steam blanching produce waste water high in BOD; in some cases, over half of the total BOD load. The volume of waste water is less with steam blanching than with water blanching. The quantity of waste water from steam blanching can be reduced by steam recycling, effective steam seals and equipment designs that minimise steam consumption. Waste water can be completely eliminated by microwave blanching, which is used in Europe and Japan.

For fruit and vegetable products which can be microbiologically sterilised at temperatures not higher than 100 °C, sterilising, which, in this case, is generally named **pasteurisation**, can be carried out in installations using hot water or steam at atmospheric pressure. The most traditionally used low temperature process is the open bath. These are metallic cylindrical or parallel piped baths, containing water heated by direct steam injection with a nozzle placed on the bottom. These baths are not generally equipped with automatic thermostats. The operating temperature is the boiling point of water at atmospheric pressure with a continuous flow of excess steam. The packs to be sterilised are loaded into large baskets; the baskets, by means of pulleys, are immersed in the baths and treated by boiling water for the required time. **Cooling** does not generally take place in the sterilising bath itself, which is thus ready to receive a new load, but in another bath containing cold running water.

For products **packaged** in glass containers, linear tunnels are used, including the phases of feeding, preheating, heating, precooling, cooling and drying. Heating is by means of saturated dry steam or hot water coming down on the packs from the top from a series of nozzles or by simple percolation from a perforated ceiling. The water is then recovered in recycling baths equipped with direct or indirect steam heating. **Cooling** is also carried out by sprinkling with water. Precooling water is partially recycled, thus keeping it at around 60 °C. The **drying** step is indispensable for the prevention of marks on the cap and above all to enable labelling and secondary online packaging. It is carried out by means of hot or cold air blowers. To sterilise low acidity products, which require temperatures greater than 100 °C, various means of heating can be used, although autoclaves are predominantly used. All high temperature sterilisers operate at pressure higher than atmospheric.

Single-phase acid products or products with small pieces, such as fruit juices, vegetable juices and purees, tomato purees, jams, marmalades and jellies, can be hot-filled. Heat sterilisation may be carried out before packaging because of the low pH and/or  $a_w$  of these products. The hot product itself sterilises the metal or glass container, so that only the caps and necks of bottles, and lids of small containers, need to be sterilised separately. Filling and hermetic closure of the container need to be carried out before the product cools down. The filling temperatures must be kept between 85 – 92 °C. In all cases, the subsequent cooling is undertaken with sterilised chlorinated water.

Finally, **aseptic packaging** is undertaken. It is a combination of sterilising plants for the product and for the containers of various types, with an isolated system of filling and sealing. The aseptic packaging of liquid products involves the following sequence of operations: heating at pre-fixed temperatures; transfer to a holding section; cooling at a temperature of around 35 °C; filling of the pre-sterilised pack, opening and kept in conditions of perfect asepsis; and closure of the pack. The type of heat-exchanger is selected according to the rheological properties of the fluid. They can be tubular of the circular crown type or scraped-film exchangers for products with high Re values and tube-in-tube-in-tube exchangers or plate exchangers for products with low Re values [124, Italy, 2002].

**Pickling** is also an important operation for the preservation of fruit and vegetables. The following process phases produce brine; fresh brine after slashing and salting (100 – 150 kg/t of white cabbage) and sour brine in the course of lactic fermentation (150 – 180 kg/t of white cabbage). The blanching process is carried out in sour brine, which produces blanching brine. Table 3.30 shows the waste water values of brine during the production of cabbage.

| Brine              | pH        | Concentration in waste water |               |                    |
|--------------------|-----------|------------------------------|---------------|--------------------|
|                    |           | BOD <sub>5</sub><br>(mg/l)   | COD<br>(mg/l) | Chloride<br>(mg/l) |
| Fresh brine        | 6.0 – 6.2 | 10000 – 30000                | 15000 – 40000 | 12000 – 15000      |
| Fermentation brine | 3.8 – 4.2 | 17000 – 50000                | 25000 – 75000 | 2500 – 20000       |
| Blanching brine    | 3.8 – 4.0 | 40000 – 55000                | 65000 – 85000 | –                  |

**Table 3.30: Waste water values of brine during the production of Sauerkraut**

### 3.3.3.5.3 Frozen vegetables

#### Materials handling and storage (A.1)

In manufacturing frozen vegetables, transportation and storage operations require energy as follows [32, Van Bael J., 1998]:

- the transportation of frozen vegetables requires 2 – 14 kWh<sub>e</sub>/t frozen vegetables. For most production lines, the electrical rating of the belts is between 5 – 30 kW<sub>e</sub>
- the storage of vegetables needs 20 – 65 kWh<sub>e</sub>/m<sup>3</sup> storage/year electricity and about 26.389 kWh/m<sup>2</sup> (95 MJ/m<sup>2</sup>) storage/year is needed in the form of hot water.

Data from the literature show that the average energy balance is made up as follows [32, Van Bael J., 1998]:

- 11 % for the evaporator fans
- 5 % for the condenser fans
- 7 % for peripheral equipment
- 77 % for compressors, of which 21 % is used for heat input via doors/hatches, 48 % used due to losses via the building shell, and 8 % through the product.

#### Sorting/screening, grading, dehulling, destemming/destalking and trimming (A.2)

The sorting operation has an electrical energy consumption of 0 – 20 kWh<sub>e</sub>/t frozen vegetables [32, Van Bael J., 1998]. Table 3.31 shows the electricity consumption during the sorting of vegetables.

| Product      | Electricity consumption<br>(kWh <sub>e</sub> /t frozen vegetables) |
|--------------|--|
| Spinach      | 0  |
| Cauliflowers | 1  |
| Peas         | 4  |
| Sprouts      | 4  |
| Beans        | 5  |
| Carrots      | 8  |

**Table 3.31: Electricity consumption during the sorting of vegetables [32, Van Bael J., 1998]**

#### Peeling (A.3)

In frozen vegetable processing, salsifies and carrots are peeled before being mechanically processed. Caustic peeling and steam peeling are two methods used. Caustic peeling needs less energy, both in terms of electricity consumption and steam consumption, than steam peeling, but creates more load for the WWTP [32, Van Bael J., 1998]. Table 3.32 shows the energy carrier and consumption for the caustic peeling of vegetables and Table 3.33 shows the energy carrier and consumption for the steam peeling of vegetables.

| Energy carrier                        | Approximate consumption |
|---------------------------------------|-------------------------|
| Hot water (kWh/t frozen vegetables)   | 0                       |
| Steam (t/t frozen vegetables)         | 0.16                    |
| Steam pressure (bar)                  | 7                       |
| Electricity (kWh/t frozen vegetables) | 2                       |

**Table 3.32: Energy carrier and consumption for the caustic peeling of vegetables**  
[32, Van Bael J., 1998]

| Energy carrier                        | Approximate consumption |
|---------------------------------------|-------------------------|
| Hot water (kWh/t frozen vegetables)   | 0                       |
| Steam (t/t frozen vegetables)         | 0.9                     |
| Steam pressure (bar)                  | 4 – 15                  |
| Electricity (kWh/t frozen vegetables) | 3.5                     |

**Table 3.33: Energy carrier and consumption for the steam peeling of vegetables**  
[32, Van Bael J., 1998]

#### Washing (A.4)

Washing, as used in the production of frozen vegetables, needs 0 – 5 kWh<sub>e</sub>/t frozen vegetables. Certain vegetables, e.g. sprouts and cauliflowers, do not require any washing and thus do not consume energy [32, Van Bael J., 1998]. Table 3.34 shows the electricity consumption for the washing of vegetables.

| Product      | Electricity consumption (kWh <sub>e</sub> /t frozen vegetables) |
|--------------|---|
| Sprouts      | 0   |
| Cauliflowers | 0   |
| Beans        | 0.5   |
| Carrots      | 2.5   |
| Salsifies    | 3   |
| Peas         | 3   |
| Spinach      | 5   |

**Table 3.34: Electricity consumption for the washing of vegetables**  
[32, Van Bael J., 1998]

#### Cutting, slicing, chopping, mincing, pulping and pressing (B.1)

Some vegetables are cut before deep freezing. The electrical energy consumption is up to 9 kWh/t frozen vegetables. Table 3.35 shows the electricity consumption of mechanical processing of vegetables before freezing.

| Product          | Electricity consumption (kWh <sub>e</sub> /t frozen vegetables) |
|------------------|---|
| Peas             | 0   |
| Sprouts          | 0   |
| Spinach          | 0   |
| Carrots (sliced) | 1   |
| Carrots (diced)  | 2.5   |
| Salsifies        | 6   |
| Beans            | 9   |
| Peas             | 0   |

**Table 3.35: Electricity consumption of mechanical processing of vegetables before freezing**  
[32, Van Bael J., 1998]

Carrots, salsifies and beans require a reasonable amount of electrical energy for mechanical processing. Other vegetables examined do not require any electricity at all [32, Van Bael J., 1998].

Blanching (E.2)

Drum and belt blanchers are used in manufacturing deep frozen vegetables. Energy consumption depends on, not only the type of blanching device, but also the type of subsequent cooling step. Typical energy consumption levels are shown in Table 3.36 and Table 3.37.

| Energy carrier                                      | Approximate consumption |
|---|-------------------------|
| Hot water (kWh/t frozen vegetables)                 | 0                       |
| Steam (t/t frozen vegetables)                       | 0.16                    |
| Steam pressure (bar)                                | 7                       |
| Electricity (kWh <sub>e</sub> /t frozen vegetables) | 0.5 – 1.3               |

**Table 3.36: Energy source and consumption for drum blanching in the deep freezing of vegetables [32, Van Bael J., 1998]**

| Energy carrier                                      | Approximate consumption |
|---|-------------------------|
| Hot water (kWh/t frozen vegetables)                 | 0                       |
| Steam (t/t frozen vegetables)                       | 0                       |
| Steam pressure (bar)                                | 0                       |
| Electricity (kWh <sub>e</sub> /t frozen vegetables) | 0.5 – 1.3               |

**Table 3.37: Energy source and consumption for countercurrent water cooling of vegetables processing [32, Van Bael J., 1998]**

Furthermore, the electricity consumption for the production of ice-water is included in the electricity consumption shown for deep freezing. For example, in terms of energy consumption, the belt blancher with water cooling has the lowest total consumption. The heat released by the cooling of the product in the cooling zone is used to preheat the vegetables. In this way, less steam is necessary for blanching. Table 3.38 shows the energy carrier and consumption for belt blancher with water cooling in vegetable processing and Table 3.39 shows the energy carrier and order of magnitude indicators of the belt blancher with air cooling in vegetable processing.

| Energy carrier                                      | Approximate consumption |
|---|-------------------------|
| Hot water (kWh/t frozen vegetables)                 | 0                       |
| Steam (t/t frozen vegetables)                       | 0.09                    |
| Steam pressure (bar)                                | 7                       |
| Electricity (kWh <sub>e</sub> /t frozen vegetables) | 2 – 9                   |

**Table 3.38: Energy carrier and consumption for a belt blancher with water cooling in vegetable processing [32, Van Bael J., 1998]**

| Energy carrier                                      | Order of magnitude indicators |
|---|-------------------------------|
| Hot water (kWh/t frozen vegetables)                 | 0                             |
| Steam (t/t frozen vegetables)                       | 0.16                          |
| Steam pressure (bar)                                | 7                             |
| Electricity (kWh <sub>e</sub> /t frozen vegetables) | 7 – 30                        |

**Table 3.39: Energy carrier and order of magnitude indicators of a belt blancher with air cooling in vegetable processing [32, Van Bael J., 1998]**

With regard to electricity consumption, the drum blancher for countercurrent water cooling has the lowest consumption. The water consumption for such an installation is rather high. The use of heavy duty fans (60 kW<sub>e</sub>) in the belt blancher with air cooling, make the electricity consumption high for this type of operation [32, Van Bael J., 1998].

### 3.3.3.5.4 Juices

Energy is consumed when the juice is concentrated by evaporation and during pasteurisation. Waste water is produced from the condensate during evaporation and during start-up, product change-over and cleaning of pasteurisers. Solid wastes are produced during the pressing of fruit and vegetables. For example, 2 % of tomatoes and 30 % of citrus fruits may be lost as solid wastes during pressing [184, Italy, 2003].

### 3.3.3.5.5 Other products

Jams, jellies and preserves are based on the production of fruit gels, that come from extracted juices, purees or the whole fruit respectively. Fruit gels are composed of pectin, acid, sugar and water. The use of sugar and additional cooking tends to increase the BOD of waste water compared with most other fruit processing. The presence of natural or added pectin in the waste water may have an adverse effect on solids settling.

## 3.3.4 Vegetable oils and fats

### 3.3.4.1 Water consumption

The processes with the most significant water consumption are crude oil production; chemical neutralisation and subsequent oil washing and deodorisation [182, Germany, 2003]. The water consumption depends on the type of process, e.g. water consumption for pressing-only is minimal, on the type of cooling and vacuum installation, and on the type and age of oilseeds, e.g. soft seeds like rapeseed require different amounts of water than soybeans [109, CIAA-FEDIOL, 2002, 182, Germany, 2003].

During crude oil production, 0.2 – 14 m<sup>3</sup> water/t oilseed are consumed for cooling purposes. Chemical neutralisation of crude oil consumes water at a rate of 1 – 1.5 m<sup>3</sup>/t of product. Deodorisation of neutralised and bleached oil and bleached edible fat consumes 10 – 30 m<sup>3</sup>/t product. The water consumed during the hardening of vegetable oil is mainly used for cooling and vacuum purposes and ranges from 2.2 – 7 m<sup>3</sup>/t oil.

In the chemical refining of edible oil, the following substances are used:

- demineralised water: 0.1 – 0.3 m<sup>3</sup>/t oil
- drinking water: 0.05 – 0.3 m<sup>3</sup>/t oil
- cooling water: 0.1 – 0.2 m<sup>3</sup>/t oil
- H<sub>2</sub>SO<sub>4</sub>: 50 – 250 kg/t soap.

#### 3.3.4.1.1 Olive oil

Olive oil producers use about 12 million tonnes of water per year [142, IMPEL, 2002], corresponding to about 5 m<sup>3</sup> water/t olive oil produced.

### 3.3.4.2 Waste water

Seed dressing and edible oil processing can generate as much as 10 – 25 m<sup>3</sup> of waste water/t product [140, World Bank (IBRD), et al., 1998]. Specific waste water production is generally in the range of 3 – 5 m<sup>3</sup>/t feedstock. The amount of waste water highly depends on the type of oil source and the technology used. For example, rapeseed crude oil production uses pressing and solvent extraction and results in 2.5 – 3.0 m<sup>3</sup> waste water/t rapeseed (7 – 12 m<sup>3</sup>/m<sup>3</sup> crude oil), where the production of refined oil from rapeseed may result in 10 – 12 m<sup>3</sup> waste water/t rapeseed [134, AWARENET, 2002].

Waste water characteristics of vegetable oil manufacturing, from several sources, reported using various units, are shown in Table 3.40, Table 3.41 and Table 3.42.

| Production sector   | Unit                                 | Waste water volume |
|---|--------------------------------------|--------------------|
| <b>Production of crude vegetable oils/fats</b>  |                                      |                    |
| Seed processing   |                                      |                    |
| Waste water   | (m <sup>3</sup> /t seed)             | 0.2 – 0.5          |
| Cooling water   | (m <sup>3</sup> /t seed)             | 0.2 – 14           |
| <b>Refining of crude vegetable oils/fats</b>  |                                      |                    |
| Acid water from soap splitting in classic oil neutralisation  | (m <sup>3</sup> /t) *                | 1 – 1.5            |
| Waste water from installation cleaning  | (m <sup>3</sup> /t) *                | up to 0.5          |
| Condensed vapours from deodorisation  | (m <sup>3</sup> /t) *                | 0.01 – 0.1         |
| Condensed vapours if steam ejectors (boosters) are used for vacuum generation for deodorisation                               | (m <sup>3</sup> /t) *                | 0.02 – 0.4         |
| Barometric falling water from vacuum end stages of distillative neutralisation and from deodorisation (without recirculation) | (m <sup>3</sup> /t) *                | 10 – 30            |
| Waste water from other vacuum equipment   | (m <sup>3</sup> /t) *                | approximately 1.5  |
| <b>Margarine production</b>   |                                      |                    |
| Rinsing and cleaning processes  | (m <sup>3</sup> /t finished product) | 0.75 – 2           |
| Water input for evaporation   | (m <sup>3</sup> /t finished product) | 0.1 **             |
| * In relation to finished refined oil   |                                      |                    |
| ** For a refrigeration capacity of 15 – 20 kW/t finished product  |                                      |                    |

**Table 3.40: Waste water production in vegetable oil manufacturing steps [65, Germany, 2002, 109, CIAA-FEDIOL, 2002]**

| Process/unit operation                        | Parameter                                 | Level   |
|---|---|---|
| Crude oil production (seed processing)        | COD load                                  | 0.1 – 1.0 kg/t seed processed                                   |
| Chemical neutralisation and soap splitting    | Waste water volume                        | 1 – 1.5 m <sup>3</sup> /t refined product                       |
|   | COD load                                  | ≤5 kg/t refined product   |
| Deodorisation                                 | Waste water volume                        | 10 – 30 m <sup>3</sup> /t refined product (once through system) |
|   | COD load                                  | ≤7 kg/t refined product   |
| Conventional chemical refining of edible oil  | Waste water volume                        | 25 – 35 m <sup>3</sup> /t refined product                       |
|   | COD load                                  | <15 kg/t refined product  |
| Combined edible oil production and processing | COD/BOD <sub>5</sub> ratio of waste water | 1.5 – 2 (normally)  |

**Table 3.41: Waste water characteristics in vegetable oil processing [182, Germany, 2003, 185, CIAA-FEDIOL, 2004]**

| Source  | Volume<br>m <sup>3</sup> /t <sup>1</sup> | BOD <sub>5</sub><br>mg/l | COD<br>mg/l | FOG<br>mg/l | SS<br>mg/l        |
|---|--|--------------------------|-------------|-------------|-------------------|
| Neutral oil washing   | 0.1                                      | 1000                     | 15000       | 100 - 500   | n.d. <sup>3</sup> |
| Neutralisation reaction<br>pH = 10 – 12   | 2.1 <sup>2</sup>                         | 4300                     | 7200        | 670         | 2900              |
| Barometric condensers<br>pH = 6.5 – 7.5   | 2  | 140 – 200                | 500 – 600   | 20 – 200    | 40 – 100          |
| Steam boiler  | 10 % of<br>steam                         | 20                       | 40          | –           | 100               |
| Water softening   | 5 % of<br>steam                          | 20                       | 40          | –           | 100               |
| Floor and equipment cleaning  | 0.1                                      | 1500                     | 2000        | n.d.        | 300               |
| <sup>1</sup> per t of crude oil <sup>2</sup> per t of ffa <sup>3</sup> n.d. = no data |  |                          |             |             |                   |

**Table 3.42: Reported untreated waste water characteristics in vegetable oil refining (cornflower, cottonseed and sunflower)**

[74, Greek Ministry for the Environment, 2001]

### 3.3.4.2.1 Olive oil

Traditional olive oil production, also called pressing, generates about 2 to 5 litres of waste water per litre of oil produced, the three-phase continuous olive oil extraction generates about 6 to 8 litres of waste water per litre of oil produced, whereas the two-phase continuous olive oil extraction generates only about 0.33 – 0.35 litres of waste water per litre of oil produced. Table 3.43 shows the characteristics of olive oil waste water using different extraction techniques.

| Technology                              | Waste water<br>volume<br>(m <sup>3</sup> /t olive oil) | BOD <sub>5</sub><br>(mg/l) | COD<br>(mg/l)   | TSS<br>(mg/l) | pH        |
|---|--|----------------------------|-----------------|---------------|-----------|
| Traditional<br>extraction<br>(pressing) | 2 – 5  | 22000 – 62000              | 59000 – 162000  | 65000         | 4.6 – 4.9 |
| Three-phase<br>extraction               | 6 – 8  | 13000 – 14000              | 39000 – 78000   | 65000         | 5.2       |
| Two-phase<br>extraction                 | 0.33 – 0.35  | 90000 – 100000             | 120000 – 130000 | 120000        | 4.5 – 5.0 |

**Table 3.43: Characteristics of olive oil mill waste water**

[74, Greek Ministry for the Environment, 2001, 86, Junta de Andalucia and Agencia de Medio Ambiente, 1994]

### 3.3.4.3 Air emissions

Dry dust is generated during seed delivery, silo storage, seed cleaning, seed preparation, meal shipment and indoor transportation/conveying. Wet dust can arise during seed preparation, meal drying and cooling, and indoor transportation/conveying.

If solvent extraction is applied, leakages and transportation can cause losses to the air. Following the extraction step, emissions of solvent (hexane) may occur during drying, cooling, storage and the transportation of meal and crude oil. Air emission levels for hexane, associated with various seed feedstocks, are shown in Table 3.44.

| Feedstock     | Hexane output<br>(kg hexane/t raw seed) |
|---------------|---|
| Soy beans     | 0.5 – 1.0                               |
| Rapeseed      | 0.5 – 1.2                               |
| Sunflowerseed | 0.5 – 1.2                               |
| Linseed       | about 2.0                               |
| Castor        | >3.0                                    |

**Table 3.44: Hexane emission to air**

[65, Germany, 2002]

In some seeds, e.g. rapeseed, the sulphur content may be high. Enzymatic and biological processes may convert sulphur compounds into hydrogen sulphide. No emission data have been reported yet during storage but significant hydrogen sulphide concentrations have been detected in the exhaust air of extractors [65, Germany, 2002]. Air emission types during the manufacture of crude vegetable oils are shown in Table 3.45.

| Degumming | Neutralisation     | Bleaching | Deodorisation                       | Hardening |
|-----------|--------------------|-----------|-------------------------------------|-----------|
|           | Volatile compounds | Odour     | Ffa<br>Volatile compounds<br>Odours |           |

**Table 3.45: Summary of air emissions in the manufacturing of crude vegetable oils [10, Environment Agency of England and Wales, 2000, 74, Greek Ministry for the Environment, 2001]**

Odour is produced in all steps where heating is involved. It results from the volatile fatty acids, organic nitrogen compounds and, in the case of rapeseed, hydrogen sulphide and organic sulphur compounds.

#### 3.3.4.4 Solid output

Depending on the type of vegetable, i.e. oilseed or oilfruit, the raw materials for vegetable oil production can almost completely be converted into products, e.g. vegetable oil, protein rich meal, fatty acids and lecithin, or by-products, e.g. for human food, animal feed and pharmaceutical products.

Solid waste, e.g. leaves, wood, pieces of metal and stones, is generated in the raw material's primary treatment step (cleaning and hulling). This is separated during the cleaning of the raw material by wind sifters, magnet separators and sieves. In oilseed production, this fraction is less than 1 % of the processed seed. Metals are sent for recycling or disposal and the remainder, such as stones and sand, is disposed of. Dust may be incinerated. In the pressing/centrifuging step, used filter clothes from seed pressing are produced and are also disposed of [161, Verband Deutscher Oelmuehlen, 2003].

In the case of chemical refining, soap stock is produced during the neutralisation of crude oil. This consists mainly of NaOH saponified ffa, but also contains phosphatides, proteins and other compounds. Normally, it is further processed in the refinery by splitting the soaps and regaining the fatty acids (acid oil). In some countries, it is possible to mix the soap stock from the chemical refining of vegetable oil with other ingredients for the production of low quality soaps or for use in meal for animal feed.

The production of solid wastes from vegetable oil refining and processing is dependent on the specific site. In bleaching operations, spent bleaching earth containing 20 – 40 % fat is produced. This makes the waste prone to spontaneous combustion. In production installations, which exclusively refine and modify edible oil, the spent bleaching earth is utilised by third parties for energy production by co-fermentation to produce biogas or to make bricks [182, Germany, 2003]. The spent catalyst is recycled to third parties for regeneration.

In mixed production installations, which produce crude oil and meal, and refine/modify the edible oil, there are further opportunities for utilisation of components of the raw material and of wastes. For example, utilisation of phospholipids in meal and utilisation of spent bleaching earth in meal, both as animal feed. The precondition for the latter example is the absence of nickel catalyst residues [161, Verband Deutscher Oelmuehlen, 2003].

Deodoriser distillate, collected from the steam distillation of refined edible oils, has a variable composition depending on the raw material and the refining process. When arising from physical refining, if the pesticide content is low, it can be used in the feed industry. Otherwise, it can be sold as a source of technical fatty acids. Those from chemical refining have higher values due to their higher tocopherol content. They are an attractive feedstock for the production of vitamin E. Due to the increasing interest in natural antioxidants, such as tocopherol, and the use of phytosterols in the food and pharmaceutical industry, the importance of this distillate will probably increase.

The types of solid/liquid output from different vegetable oil processing unit operations, are shown in Table 3.46.

|                            | <b>Degumming</b> | <b>Neutralisation</b>             | <b>Bleaching</b>                                 | <b>Deodorisation</b> | <b>Hardening</b>                        |
|----------------------------|------------------|-----------------------------------|--|----------------------|---|
| <b>Solid/liquid output</b> | Mucilage         | Soapstock and spent acids/alkalis | Spent earth containing gums, metals and pigments | None                 | Spent catalysts and spent filtering aid |

**Table 3.46: Summary of key solid/liquid emissions and by-products in the manufacturing of crude vegetable oils**  
[10, Environment Agency of England and Wales, 2000, 74, Greek Ministry for the Environment, 2001]

A comparison between the solid output from olive oil production and seed oil production is given in Table 3.47.

| <b>Type of production</b> | <b>Raw material pretreatment</b>            | <b>Conditioning of raw material</b> | <b>Pressing/ centrifugation</b>                | <b>Solvent extraction</b>              |
|---------------------------|---|-------------------------------------|--|--|
| Waste from olives         | Extraneous material, e.g. leaves and stones | None                                | Used filter cloths, pressed cake, olive stones | Extracted cake, meal and filter debris |
| Waste from oilseeds       | Extraneous material, e.g. leaves and stones | None                                | Used filter cloths                             | None                                   |

**Table 3.47: Summary of solid output from manufacturing crude vegetable oils**  
[10, Environment Agency of England and Wales, 2000, 185, CIAA-FEDIOL, 2004]

Types and quantities of wastes and by-products are summarised in Figure 3.10.

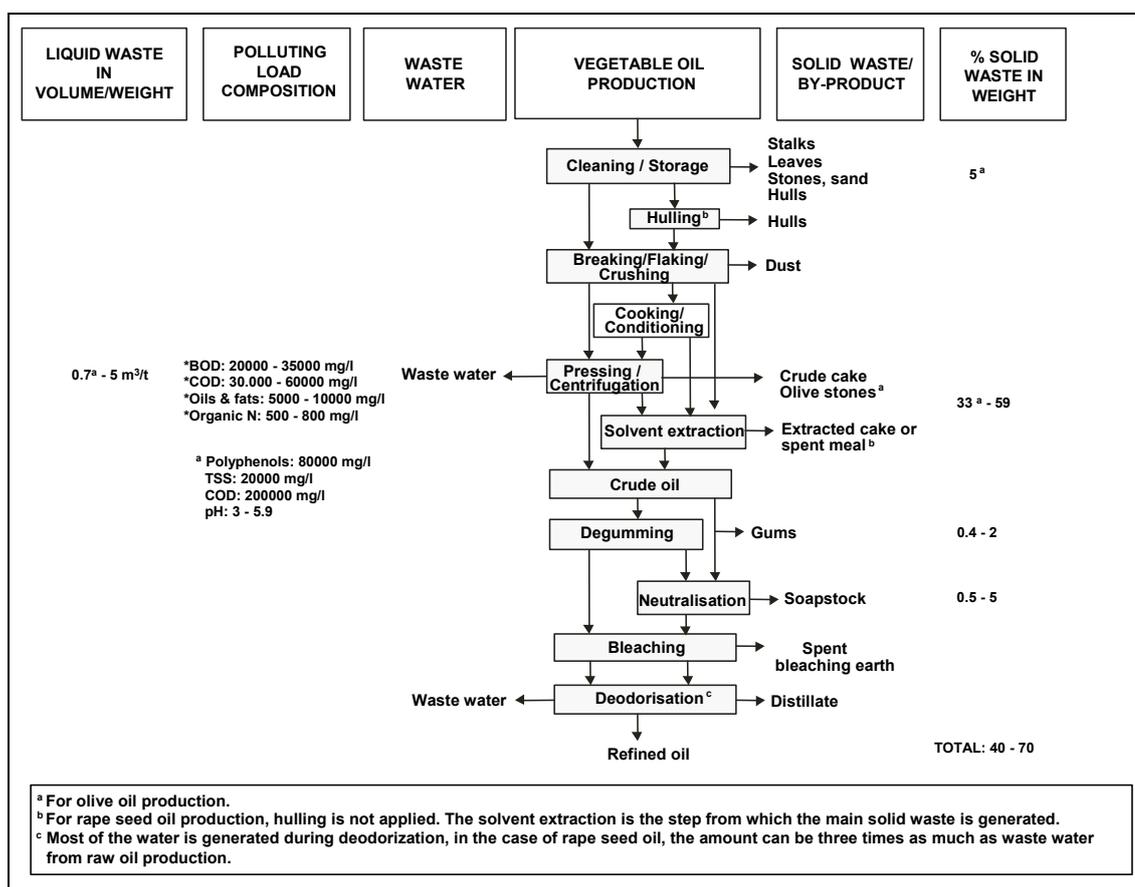


Figure 3.10: Types and quantities of wastes and by-products generated in vegetable oil processing [134, AWARENET, 2002]

### 3.3.4.4.1 Oilseed

Typically the yield from oilseed processing is almost 100 %. Products from oilseed processing and vegetable oil refining are mainly vegetable oil, protein rich meal, lecithin and ffa (acid oil). Ffa may contain tocopherol, a natural antioxidant. They can be used as a feedstock for the production of vitamin E. By-products may either be used as animal feed or burnt as fuels [182, Germany, 2003, 185, CIAA-FEDIOL, 2004].

Chemical refining produces soap stock during the neutralisation of crude oil. This consists mainly of the sodium salts of the separated ffa, but also includes triacylglycerols, phosphatides, proteins, pigments and other compounds. Normally soap stock is further processed in the refinery by splitting the soaps and regaining the ffa. It is possible to mix the soap stock from the chemical refining of vegetable oil with other ingredients to produce low quality soaps or for use in meal for animal feed [182, Germany, 2003, 185, CIAA-FEDIOL, 2004].

Crude cake and spent meal are either incinerated or used in the production of fuels and other products such as kernel oil and activated carbon. They can also be used in animal feed. Exhausted cake, which has an oil content lower than 1 %, is usually formed into pellets or briquettes and its main application is animal feed, but it may also be composted or burnt.

Lecithin is an edible by-product consisting of a mixture of phosphatides with minor quantities of glycolipids and oligosaccharides. It is known to have outstanding functional characteristics, such as emulsification properties, spreadability and wetting ability. After a very simple and inexpensive purification, it can be used in a number of applications in food, cosmetics and pharmaceuticals. Soybean oil is the most important source of lecithin, although other vegetable oils such as maize, sunflower or ground-nut oil also yield suitable lecithin.

In oilseed processing, 0.7 – 0.8 tonnes of solid output per tonnes of raw material are generated. The major part of it is of vegetable origin, e.g. cake and meal. This is either further treated to extract the residual oil content, which may be as high as 10 – 20 %, used in animal feed, sent for heat recovery, or used without or after composting as a soil conditioner.

#### 3.3.4.4.2 Olive oil

In crude olive oil production, the traditional system, i.e. pressing, and the three-phase system produce a press cake and a considerable amount of waste water while the two-phase system, which is mainly used in Spain, produces a paste-like waste called “alperujo” that has a higher water content and is more difficult to treat than traditional solid waste. The water content of the press cake, composed of crude olive cake, pomace and husk, is about 30 % if it is produced by traditional pressing technology and about 45 – 50 % using decanter centrifuges. The press cake still has some oil that is normally recovered in a separate installation. The exhausted olive cake is incinerated or used as a soil conditioner on olive groves.

#### 3.3.4.5 Energy

The energy consumption during the production of crude vegetable oil depends on the type of raw material, the equipment and the manufacturing processes. Heating, cooling, drying, milling, pressing, evaporation and distillation are the major energy consuming steps. Cold pressing, without heat conditioning of the raw material, which is especially used for olive oil production, needs twice as much energy as the pressing of heat conditioned oilseeds. Steam consumption is in the range 200 – 500 kg steam/t processed seed (155 – 390 kWh/t) and the electricity need is in the range 25 – 50 kWh/t processed seed (90 – 180 MJ/t) [109, CIAA-FEDIOL, 2002, 182, Germany, 2003, 185, CIAA-FEDIOL, 2004]. Table 3.48 shows energy and steam consumption for some processes in crude vegetable oil refining in German installations. Further energy consumption figures for some processes are given in techniques described in Sections 4.7.4.2, 4.7.4.3, and 4.7.4.4.

| Processing step | Total energy consumption | Steam consumption <sup>1</sup> | Electricity Consumption |
|-----------------|--------------------------|--------------------------------|-------------------------|
|                 | (MJ/t final product)     | (MJ/t final product)           | (MJ/t final product)    |
| Neutralisation  | 145 – 330                | 112 – 280                      | 22 – 44                 |
| Soap splitting  | 620 – 2850*              | 560 – 2800*                    | 11 – 36*                |
| Deodorisation   | 510 – 1350               | 420 – 1120                     | 60 – 150                |
| Hardening       | 400 – 1000               | n.d.                           | n.d.                    |
| Bleaching       | n.d.                     | n.d.                           | n.d.                    |
|                 | (kWh/t final product)    | (kWh/t final product)          | (kWh/t final product)   |
| Neutralisation  | 40 – 92                  | 31 – 78                        | 6 – 12                  |
| Soap splitting  | 172 – 792*               | 156 – 778*                     | 3 – 10*                 |
| Deodorisation   | 142 – 375                | 117 – 311                      | 17 – 42                 |
| Hardening       | 111 – 278                | n.d.                           | n.d.                    |
| Bleaching       | n.d.                     | n.d.                           | n.d.                    |

<sup>1</sup> Calculated using 2.8 x kg steam/t = MJ/t  
 \*MJ/t soap or kWh/t soap  
 n.d. (no data available)  
 Final product = refined vegetable oil

**Table 3.48: Energy consumption in crude vegetable oil refining [65, Germany, 2002, 109, CIAA-FEDIOL, 2002]**

### 3.3.4.6 Chemicals used

Ideally, the extraction solvent should only dissolve glycerides and leave undesirable components such as colouring matter, gums, and phospholipids. The solvents must not contain toxic components, and should be recoverable with minimum loss, be safe in handling, and be readily removable from the extracted material. For these reasons, aliphatic hydrocarbons, especially hexane, are used almost exclusively. Technical hexane with a boiling point range of 55 – 70 °C has proved to be the optimum solvent. Hexane can be readily removed from the oil at temperatures below 100 °C under vacuum and can be stripped from the meal with steam. The solubility of hexane in the condensed water is only 0.1 %.

Alcohols like ethanol, isopropanol, methanol, butanol, and furfural are especially suited to the extraction of relatively wet materials. The extraction of oilseed with alcohols leads to relatively high concentrations of phosphatides, glycolipids, carbohydrates, and similar constituents in the crude oil, although the glycerides can, in principle, be concentrated by cooling or extraction of the alcoholic solutions. Alcohols are generally not used as primary extraction solvents. However, they are occasionally used as secondary extraction solvents to remove gossypol from cottonseed meal, thioglycosides from rapeseed meal, sugars from soybean meal (to produce protein concentrates), and alkaloids from bitter lupine meal. A new technology is oil supercritical propane or carbon dioxide extraction, where extraction takes place under high pressure. This process is reserved for special products of high intrinsic value because of the high equipment costs involved [87, Ullmann, 2001].

Chemicals are used in the chemical neutralisation of crude oil. 1 – 6 kg/t oil NaOH and 0.1 - 2 kg/t oil is used depending on the function of the type of oil and the ffa content of the pre-degummed or not, crude oil. If phosphoric acid is used, 0.1 – 2.0 kg/t oil is consumed. Alternatively, citric acid may also be used, its consumption is 0.1 – 1.0 kg/t oil. Sulphuric acid used in soap-stock splitting amounts to 100 – 250 kg H<sub>2</sub>SO<sub>4</sub>/t soap [109, CIAA-FEDIOL, 2002].

### 3.3.5 Dairy products

#### 3.3.5.1 Water

##### 3.3.5.1.1 Water consumption

Water consumption is mainly associated with cleaning operations. The factors affecting water consumption in European dairies are [160, European Dairy Association, 2002]:

- availability of surface and groundwater for cooling
- time and amount of water used for rinsing
- characteristics of CIP programmes
- maintenance, e.g. repair of leaks.

A reasonably efficient consumption of water is reported to be around 1 – 5 l/kg milk [134, AWARENET, 2002], however, it is reported that a water consumption of 0.8 – 1.0 l/kg milk can be achieved by using advanced equipment and a good operation [74, Greek Ministry for the Environment, 2001]. According to a German survey, 132 dairies used, on average in 1999, 2.06 l/kg of milk [39, Verband der Deutschen Milchwirtschaft (German Dairy Association), 2001]. Table 3.49 shows water consumption in European dairies. Table 3.50 shows water consumption for some Nordic dairies.

| Product                                    | Water consumption*<br>(l/kg processed milk) |     |
|--|---|-----|
|  | Min   | Max |
| Market milk and yoghurt                    | 0.8   | 25  |
| Cheese and whey                            | 1.0   | 60  |
| Milk powder, cheese and/or liquid products | 1.2   | 60  |

\*Cooling water is included

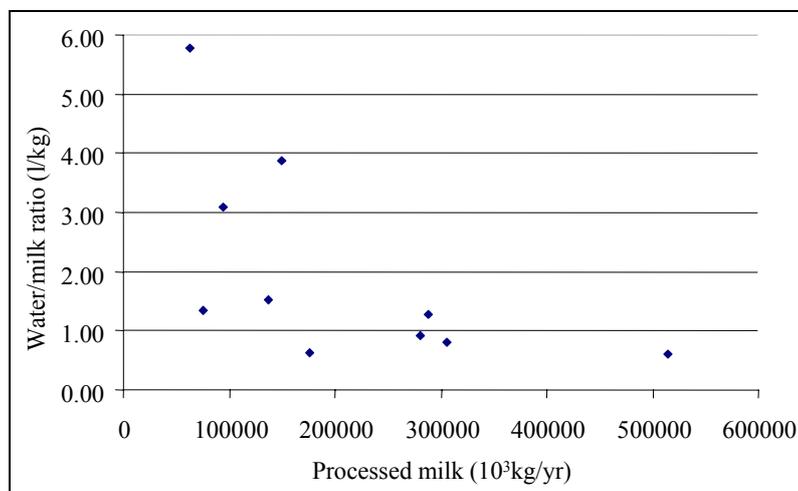
**Table 3.49: Water consumption in European dairies**  
[160, European Dairy Association, 2002]

| Product                                    | Water consumption<br>(l/l processed milk) |                    |                  |                  |
|--|---|--------------------|------------------|------------------|
|  | Sweden                                    | Denmark            | Finland          | Norway           |
| Market milk and yoghurt                    | 0.96 – 2.8<br>(8)                         | 0.60 - 0.97<br>(3) | 1.2 – 2.9<br>(8) | 4.1<br>(1)       |
| Cheese and whey                            | 2.0 – 2.5<br>(4)                          | 1.2 – 1.7<br>(5)   | 2.0 – 3.1<br>(2) | 2.5 – 3.8<br>(2) |
| Milk powder, cheese and/or liquid products | 1.7 – 4.0<br>(7)                          | 0.69 – 1.9<br>(3)  | 1.4 – 4.6<br>(2) | 4.6 – 6.3<br>(2) |

Figures in brackets show the number of dairy installations in each category

**Table 3.50: Water consumption for some Nordic dairies**  
[42, Nordic Council of Ministers, et al., 2001]

In the UK dairy industry, there is a wide variation in the water consumption/amount of milk processed ratio, compared to the volume of the milk received for processing per installation, as shown in Figure 3.11.



**Figure 3.11: Water consumption/processed milk ratio as a function of the quantity of processed milk**  
[94, Environment Agency of England and Wales, 2002]

Seven ice-cream installations in Nordic countries have reported a water consumption in the range 3.6 – 10.3 l/kg of produced ice-cream [42, Nordic Council of Ministers, et al., 2001]. For ice-cream installations where no water recycling is applied in the cooling system, a water consumption of 10 – 325 l/kg of product has been reported [118, CIAA-EDA, 2002].

### 3.3.5.1.2 Waste water

Waste water is the main environmental issue in the dairy sector. The sector uses a vast amount of water, and generates a huge amount of waste water in maintaining the required level of hygiene and cleanliness. Data reported for specific waste water discharge for dairy activities in Austria are shown in Table 3.51. Waste water volume in a well managed installation is reported to be about 1 – 2 l/kg of milk processed.

| Type of product   | Waste water volume<br>(l/kg of milk processed) |
|---|--|
| “White” products, e.g. milk, cream and yoghurt                                | 3  |
| “Yellow” products, e.g. butter and cheese                                     | 4  |
| “Special” products, e.g. concentrates of milk or whey and dried milk products | 5  |

**Table 3.51: Approximate volumes of waste water in dairy activities**  
[152, Austria, 2002]

In the UK, around 14 million m<sup>3</sup> of milk is produced for processing each year. It is reported that a new dairy in the UK is achieving a 1:1 volume of milk processed:waste water volume ratio, i.e. one litre of waste water for each litre of milk processed and that a 1.5:1 ratio is achievable in existing dairies. A comparison is reported between a dairy generating 2 litres of waste water per litre of milk processed. This would produce around 28 million m<sup>3</sup>/year of waste water for disposal to a WWTP. If this waste water is considered to have an average COD strength of 3000 mg/l, then the total loading would be around 84000 t COD/yr, equivalent to the waste of more than two million people. Also, if 1 m<sup>3</sup> of milk is released into a watercourse, its oxygen depleting potential, in terms of BOD<sub>5</sub> load, is equivalent to the daily raw sewage of 1500 – 2000 people.

Untreated dairy waste waters have an average BOD load ranging from 0.8 to 2.5 kg BOD/t milk. Other significant pollutants present in the waste water are phosphorus, nitrogen and chloride. Individual waste water streams of a wide pH range are produced. The temperature of the waste water streams may also need to be considered. The waste water may contain pathogens from contaminated materials or production processes [140, World Bank (IBRD), et al., 1998]. Table 3.52 gives data on the typical untreated waste water from dairy processing.

| Component   | Range                       |
|---|-----------------------------|
| SS  | 24 – 5700 mg/l              |
| TSS   | 135 – 8500 mg/l             |
| COD   | 500 – 4500 mg/l**           |
| BOD <sub>5</sub>  | 450 – 4790 mg/l             |
| Protein   | 210 – 560 mg/l              |
| Fat   | 35 – 500 mg/l               |
| Carbohydrate  | 252 – 931 mg/l              |
| Ammonia -N  | 10 – 100 mg/l**             |
| Nitrogen  | 15 – 180 mg/l               |
| Phosphorus  | 20 – 250** mg/l             |
| Sodium  | 60 – 807 mg/l               |
| Chloride  | 48 – 469 (up to 2000*) mg/l |
| Calcium   | 57 – 112 mg/l               |
| Magnesium   | 22 – 49 mg/l                |
| Potassium   | 11 – 160 mg/l               |
| pH  | 5.3 – 9.4 (6 – 10*)         |
| Temperature   | 12 – 40 °C                  |
| Actual levels will depend on the use of in-process techniques to prevent water contamination (not reported) |                             |
| * CIAA comments [83, CIAA, 2001]  |                             |
| ** German comments [99, Germany, 2002]  |                             |

**Table 3.52: Reported untreated dairy waste water contamination levels [13, Environment Agency of England and Wales, 2000]**

Volume and pollution levels of dairy waste water in Europe are shown in Table 3.53. The typical BOD of various milk products is shown in Table 3.54.

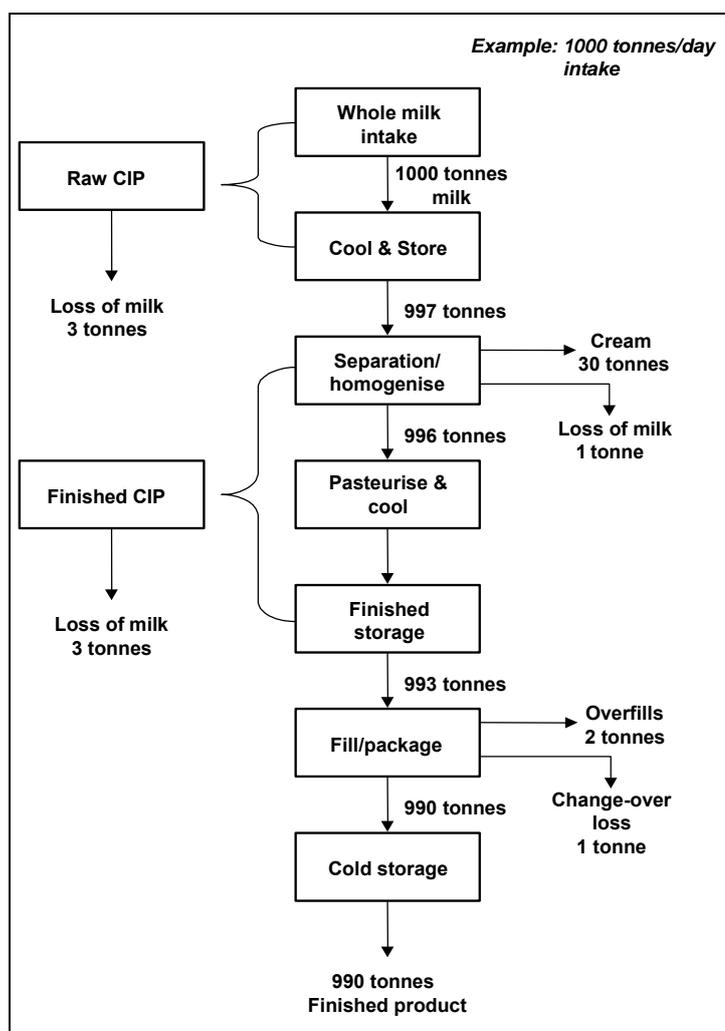
| Product                 | Waste water volume (l/kg) | Parameters (mg/kg of processed milk) |             |             |
|-------------------------|---------------------------|--------------------------------------|-------------|-------------|
|                         |                           | COD                                  | Total N     | Total P     |
| Market milk and yoghurt | 0.9 – 25                  | 2.0 – 10                             | 0.05 – 0.14 | 0.01 – 0.02 |
| Cheese                  | 0.7 – 60                  | 0.8 – 13                             | 0.08 – 0.2  | 0.01 – 0.05 |
| Milk and whey powder    | 0.4 – 60                  | 0.5 – 6                              | 0.03 – 0.3  | 0.01 – 0.2  |
| Ice-cream               | 2.7 – 7.8                 |                                      |             |             |

**Table 3.53: Volume and pollution levels of dairy waste water in Europe [42, Nordic Council of Ministers, et al., 2001, 160, European Dairy Association, 2002]**

| Product      | BOD <sub>5</sub> (mg/kg of product) |
|--------------|-------------------------------------|
| Whole milk   | 104000                              |
| Skimmed milk | 67000                               |
| Double cream | 399000                              |
| Yoghurt      | 91000                               |
| Ice-cream    | 292000                              |
| Whey         | 34000                               |

**Table 3.54: Typical BOD levels of various milk products [13, Environment Agency of England and Wales, 2000]**

The largest proportion of waste water is cleaning water. This is used for equipment cleaning, e.g. line purging at product change-over, start-up, shut-down and change-over of HTST pasteurisation units as well as some product washing. Product loss during milk manufacture can be as high as 3 – 4 %, with normally 0.5 – 1.5 % of product being wasted. These milk losses can occur during cleaning; the run-off during the start-up, shut-down or change-over of an HTST unit; or from accidental spills. Product losses to waste water can contribute greatly to the COD, nitrogen and phosphorous content. Typical milk losses are shown in Figure 3.12.



**Figure 3.12: Typical losses of milk in the dairy industry**  
 [11, Environment Agency of England and Wales, 2000]

Although CIP operations contribute to saving water, energy and chemicals, they still generate large volumes of waste water, which may have a high or low pH due to the use of acid and alkaline cleaning solutions. The use of phosphoric and nitric acids will increase the phosphate and nitrate content of the waste water. Badly designed CIP systems and inadequate product removal prior to the start of the CIP cycle cause large quantities of product to enter the cleaning water. Some UK dairy sites have achieved a reduction of 40 – 65 % in their waste water COD as a result of improvements in this area [43, Envirowise (UK) and Entec UK Ltd., 1999]. Waste water with high concentrations of dissolved solids is produced by the regeneration of ion exchange resins and from membrane backwashing.

Large evaporators are used in the production of milk concentrate, which is the first stage in the production of milk powder, and dried whey. The evaporated water is condensed, giving rise to large quantities of condensate. Normally this is clean, but vacuum leaks on the condensers can lead to contamination with product. Condensate may be used in other processes, such as preheating incoming milk or as cleaning water after suitable treatment, e.g. RO followed by disinfection.

There are smaller contributions to the waste water from the non-dairy ingredients used in some of the products and from lubricants. SS are associated with coagulated milk, particles of cheese curd and non-dairy ingredients.

For cheese manufacturing, about 90 % of the milk used ends up as whey. Sweet whey is often recovered and used as a food grade additive. Salt whey, produced after salt has been added to the curd to remove additional liquid, is not suitable for this application unless the salt is removed by RO. The RO permeate is highly saline. Unless whey is processed quickly it becomes acidic due to lactic acid formation. If acid whey is discharged to a WWTP, it may cause low pH levels.

This waste water has an extremely variable composition, depending on the technology applied and whether whey is segregated. The characteristics of a typical waste water from cheese manufacturing are shown in Table 3.55.

| Parameter          | Installation with whey recovery | Installation without whey recovery |
|--------------------|---------------------------------|------------------------------------|
|                    | mg/l                            |                                    |
| BOD <sub>5</sub>   | 2397                            | 5312                               |
| COD                | 5312                            | 20559                              |
| Fats               | 96                              | 463                                |
| N <sub>total</sub> | 90                              | 159                                |
| P <sub>total</sub> | 26                              | 21                                 |

**Table 3.55: Composition of cheese manufacturing waste water [134, AWARENET, 2002]**

### 3.3.5.2 Air emissions

Many dairies produce thermal energy on site. Emissions of carbon dioxide, sulphur dioxide and nitrogen oxides derive from the energy production in the boiler plants and are not discussed here. Many dairies still use halogenated compounds in their cooling systems, mostly HCFCs, but small amounts of CFCs are still used in some countries. The interaction of halogen refrigerants with ozone in the air has resulted in the progressive prohibition of the placing on the market and use of ozone depleting substances and of products and equipment containing those substances [202, EC, 2000]. There is currently a proposal for a Regulation of the European Parliament and of the Council on certain fluorinated greenhouse gases [246, EC, 2003].

Ammonia used in cooling systems may leak or accidental releases may occur which also result in odour complaints. Odour problems are usually related to waste water treatment operations. Dairy installations situated in urban areas usually receive complaints regarding noise, e.g. associated with vehicle movements, refrigeration and UHT installations.

Bag filters can be used to reduce dust emissions to <5 mg/Nm<sup>3</sup>. Filters use significantly less energy than cyclones and produce less noise. If filtering installations suitable for CIP are used for outgoing air, it is not necessary to use cyclones allowing huge energy savings and noise reductions to be achieved. The filter powder of food quality can be used for other purposes.

### 3.3.5.3 Solid output

Packaging waste such as paper, wooden pallets, big bags and plastic films, and other wastes need to be re-used or disposed of. Wastes are also produced in fat traps, and in flotation and biological WWTPs. As well as these wastes, major solid or liquid wastes and by-products are also produced, e.g. whey residues, non-conforming products, sludge from separation during milk clarification and filtration, product loss on the heat transfer surface and discharged in the waste water during the cleaning of the equipment, curd waste, and small pieces of cheese. Whey may be segregated and processed to make further useful products. The non-conforming products are used as animal feed or sent for landfill and the sludge produced in the WWTP is sent for landfill.

Product losses in the dairy industry, expressed as a percentage of the volume of milk or fat or whey processed, are summarised in Table 3.56.

| Type of processing               | Product losses (%) |      |      |
|----------------------------------|--------------------|------|------|
|                                  | Milk               | Fat  | Whey |
| Butter/transport of skimmed milk | 0.17               | 0.14 | –    |
| Butter and skimmed milk powder   | 0.60               | 0.20 | –    |
| Cheese                           | 0.20               | 0.10 | 1.6  |
| Cheese and whey evaporation      | 0.20               | 0.10 | 2.2  |
| Cheese and whey powder           | 0.20               | 0.10 | 2.3  |
| Consumer milk                    | 1.9                | 0.7  | –    |
| Full-cream milk powder           | 0.64               | 0.22 | –    |

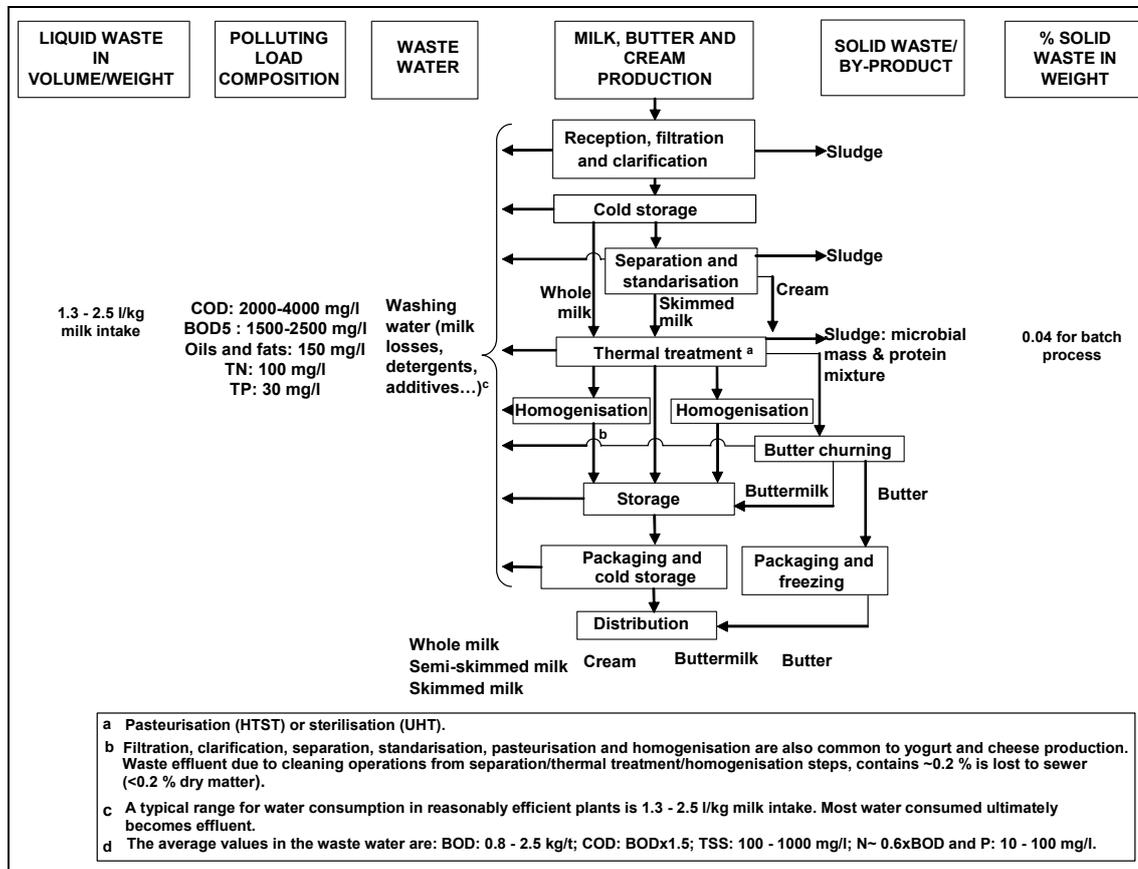
**Table 3.56: Product losses in some processes in the dairy industry**  
[140, World Bank (IBRD), et al., 1998]

Reported solid outputs per tonne of processed milk are shown in Table 3.57.

|                         | Solid output (kg) | WWTP sludges |
|-------------------------|-------------------|--------------|
| Liquid milk and yoghurt | 1.7 – 45.0        | 0.2 – 18.0   |
| Cheese                  | 1 – 20            | 0.2 – 24     |
| Milk and whey powder    | 0.5 – 16          | 3 – 30       |

**Table 3.57: Solid output per tonne of processed milk**  
[160, European Dairy Association, 2002]

The main sources of wastes produced in milk, yoghurt and cheese processing are indicated in Figure 3.13, Figure 3.14, and Figure 3.15.



**Figure 3.13: Type and amount of wastes produced in milk processing**  
[134, AWARENET, 2002]

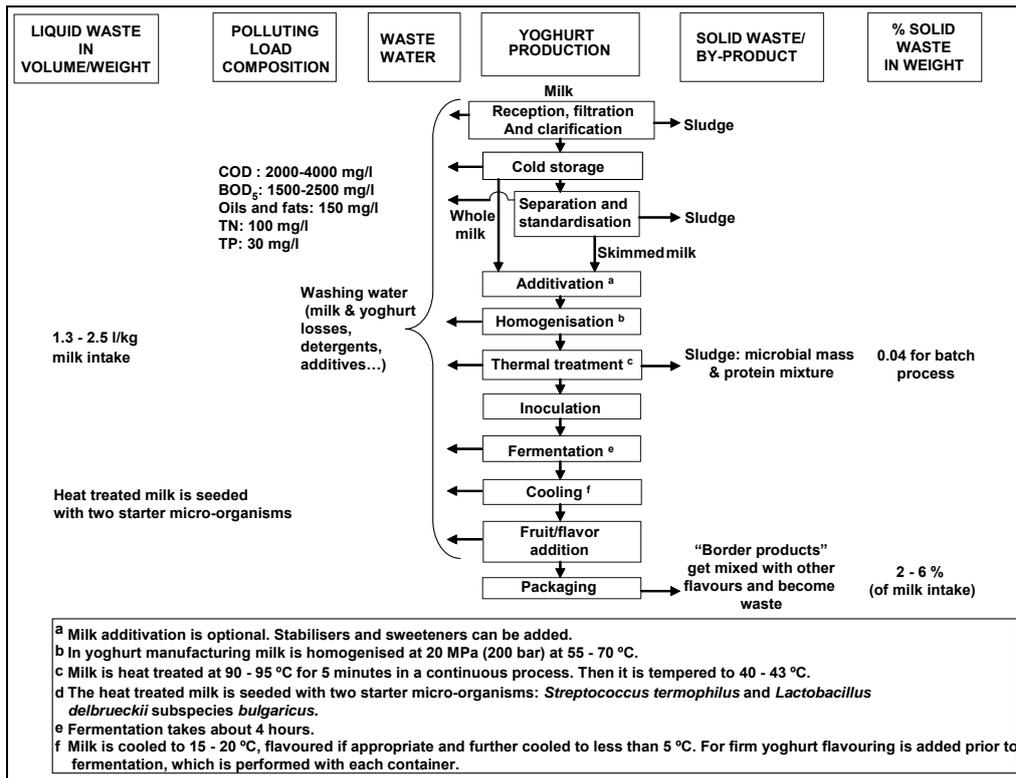


Figure 3.14: Type and amount of wastes produced in yoghurt processing [134, AWARENET, 2002]

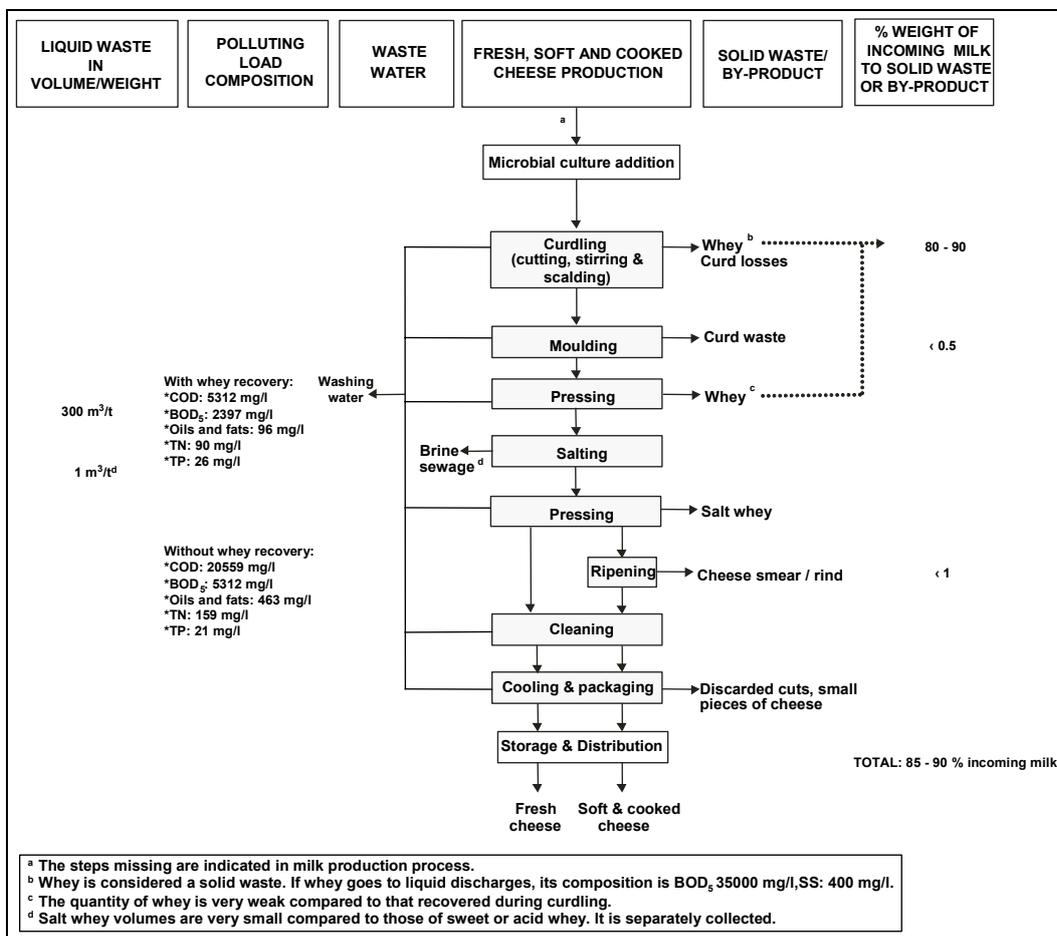


Figure 3.15: Type and amount of wastes produced in cheese processing

[134, AWARENET, 2002]

Table 3.58 gives the reported total amounts of waste produced in Nordic dairy installations and their disposal. The figures do not include waste that is intended for animal feed. Non-conforming products sent for landfilling are included.

| Products                       | Total solid waste (kg/1000 l) | Of which |             |           |                      |
|--------------------------------|-------------------------------|----------|-------------|-----------|----------------------|
|                                |                               | Recycled | Incinerated | Composted | Sent for landfilling |
| Market milk, cultured products | 1.7 – 14<br>(13)              | 5 – 41 % | 0 – 48 %    | 0 – 14 %  | 14 – 95 %            |
| Cheese, whey, powder           | 0.5 – 10<br>(17)              | 1 – 91 % | 0 – 80 %    | 0 – 2 %   | 9 – 88 %             |
| Ice-cream (kg/1000 kg)         | 35 – 48<br>(4)                | 4 – 33 % | 0 – 6 %     | 0 %       | 67 – 95 %            |

\* The figures in brackets show the number of dairy installations in each category

**Table 3.58: Production and disposal of solid wastes from some Nordic dairies**  
[42, Nordic Council of Ministers, et al., 2001]

The overall solid output for ice cream manufacturing reported for Europe is in a wider range, i.e. 30 – 150 kg/t product [118, CIAA-EDA, 2002].

### 3.3.5.4 Energy

Dairies have a significant energy consumption. Around 80 % of the energy is consumed as thermal energy from the combustion of fossil fuels to generate steam and hot water. It is used for heating operations and cleaning. The remaining 20 % is consumed as electricity to drive machinery, refrigeration, ventilation, and lighting. The most energy consuming operations are the evaporation and drying of milk [42, Nordic Council of Ministers, et al., 2001]. In pasteurisation, e.g. significant energy is also needed for the heating and cooling steps. Recovery of heat by heat-exchangers can be applied. Evaporation is normally combined with vapour recompression. A wide range of energy consumption data has been reported for the European dairy industry. Figures are included in Table 3.59.

| Products                | Energy consumption (GJ/t processed milk) |            | Remarks   |
|-------------------------|--|------------|---|
|                         | Electricity                              | Fuel       |   |
| Market milk and yoghurt | 0.15 – 2.5                               | 0.18 – 1.5 | Minimum for liquid milk, maximum for specialities                                   |
|                         | 0.09 – 1.11*                             |            |   |
| Cheese                  | 0.08 – 2.9                               | 0.15 – 4.6 | Depends on the type of cheese and production run. Maximum fuel for whey evaporation |
|                         | 0.06 – 2.08*                             |            |   |
| Milk and whey powder    | 0.06 – 3.3                               | 3 – 20     | Maximum fuel for whey products  |
|                         | 0.85 – 6.47*                             |            |   |

\* approximate kWh/l (assuming milk has a density of 1 kg/l)

**Table 3.59: Energy consumption in European dairies**  
[160, European Dairy Association, 2002]

Similar figures are reported for Nordic dairies, as shown in Table 3.60.

| Products                                   | Total energy consumption from electricity and fuel oil<br>(kWh/l processed milk) |                    |                    |                    |
|--|--|--------------------|--------------------|--------------------|
|  | Sweden   | Denmark            | Finland            | Norway             |
| Market milk and cultured products          | 0.11 – 0.34<br>(8)*  | 0.07 – 0.09<br>(3) | 0.16 – 0.28<br>(8) | 0.45<br>(1)        |
| Cheese and whey                            | 0.15 – 0.34<br>(4)   | 0.12 – 0.18<br>(4) | 0.27 – 0.82<br>(3) | 0.21<br>(1)        |
| Milk powder, cheese and/or liquid products | 0.18 – 0.65<br>(7)   | 0.3 – 0.71<br>(3)  | 0.28 – 0.92<br>(2) | 0.29 – 0.34<br>(2) |

\* Figures in brackets show the number of dairy installations in each category

**Table 3.60: Total energy consumption for some Nordic dairies**  
[42, Nordic Council of Ministers, et al., 2001]

More energy is used in dairies where butter, as well as drinking milk, is produced and where the production of powdered milk is greater. Four installations of the ice-cream industry in Nordic countries have reported to have a total energy consumption in the range 0.75 - 1.6 kWh/kg of ice-cream produced [42, Nordic Council of Ministers, et al., 2001]. Other reports show an energy consumption of 2 – 10 GJ/t ice-cream produced [118, CIAA-EDA, 2002].

### 3.3.5.5 Consumption of chemicals

Most of the chemicals are used for the cleaning and disinfection of process machinery and pipelines. Fresh product dairies mainly use caustic and nitric acid and some disinfectants, such as hydrogen peroxide, peracetic acid and sodium hypochlorite. Disinfection agents are also used in a range of 0.01 – 0.34 kg/t processed milk [160, European Dairy Association, 2002]. Table 3.61 shows the consumption of cleaning agents used in European dairies. Of the total chemical consumption in Nordic dairies, 55 % is caustic and 30 % nitric acid. Table 3.62 shows the consumption of cleaning chemicals used in some Nordic dairies.

| Products                | Consumption of cleaning agents<br>(kg/t processed milk) |                          |            |
|-------------------------|---|--------------------------|------------|
|                         | NaOH, 100 %   | HNO <sub>3</sub> , 100 % | Detergents |
| Market milk and yoghurt | 0.2 – 10  | 0.2 – 5.0                | *          |
| Cheese                  | 0.4 – 5.4   | 0.6 – 3.8                | 0.1 – 1.5  |
| Milk and whey powder    | 0.4 – 5.4   | 0.8 – 2.5                | *          |

Values vary with the length and capacity of production runs  
\*Not applicable

**Table 3.61 Consumption of cleaning agents used in European dairies**  
[160, European Dairy Association, 2002]

| Product                     | Caustic<br>as NaOH, 100 %                           | Nitric acid<br>as HNO <sub>3</sub> , 100 % |
|-----------------------------|---|--|
|                             | kg/m <sup>3</sup> of processed milk or tonne of ice |  |
| Market milk and yoghurt     | 0.2 – 0.9<br>(13)                                   | 0.1 – 1.0<br>(13)                          |
| Cheese/milk and whey powder | 0.4 – 5.4<br>(14)                                   | 0.6 – 3.8<br>(14)                          |
| Ice-cream                   | 0.5 – 4.5<br>(7)                                    | 0.2 – 2.5<br>(7)                           |

Figures in brackets show the number of dairy installations in a category

**Table 3.62: Consumption of cleaning chemicals used in some Nordic dairies**  
[42, Nordic Council of Ministers, et al., 2001]

Whey processing involving electro dialysis, ion exchange, ultra and nanofiltration, requires large amounts of phosphoric, sulphuric and hydrochloride acid as well as potassium hydroxide and sodium hypochlorite. Chelating agents are widely used in dairy cleaning operations and are discussed in Sections 4.3.8.2 to 4.3.8.2.5.

### 3.3.5.6 Noise

Noise is caused by the movement of milk tankers and distribution lorries; evaporators, spray driers, and cooling condensers [42, Nordic Council of Ministers, et al., 2001]. Bag filters use significantly less energy than cyclones and produce less noise. If filtering installations suitable for CIP are used for outgoing air, it is not necessary to use cyclones allowing huge energy savings and noise reductions to be achieved.

### 3.3.6 Dry pasta

The basic raw material for the production of high quality pasta products is semolina from durum wheat. 1.04 – 1.05 tonnes semolina are used to produce 1 tonne of pasta. Water and other ingredients are added to make a stiff dough containing approximately 31 % water. The dough is forced under pressure through dies of an extrusion auger. The major environmental issue in this sector is energy consumption as all pasta manufacturing processes involve drying.

#### 3.3.6.1 Water

Water consumption is between 22 – 30 m<sup>3</sup>/t product. Water is mainly used as an ingredient. The production of process related polluted waste water is reported to be insignificant [117, CIAA-UNAFPA, 2002].

#### 3.3.6.2 Emissions to air

Thermal energy is obtained in boilers generally using natural gas. Superheated water, of 130 - 160 °C and 4 – 7 bar as measured in a hydraulic air vessel, is used to dry pasta. Typical air emission values are shown in Table 3.63.

| Parameter                             | Range                                   |
|---------------------------------------|---|
| Carbon dioxide                        | 130 – 160 kg CO <sub>2</sub> /t product |
| Carbon monoxide                       | Lower than 100 mg/Nm <sup>3</sup> *     |
| NO <sub>x</sub>                       | Lower than 350 mg/Nm <sup>3</sup> *     |
| * At 3 % O <sub>2</sub> concentration |   |

**Table 3.63: Air emissions from pasta manufacturing**  
[117, CIAA-UNAFPA, 2002, 150, Unione Industriali Pastai Italiani, 2002]

#### 3.3.6.3 Energy

The drying step utilises about 85 – 90 % of the thermal energy and 50 – 60 % of the electricity consumption of the installation. These figures may even be higher for lines producing special products such as nests or lasagne. Air conditioning of the workspace needs 35 – 50 kWh/t energy.

In evaluating energy consumption in the sector, the results of a study on pasta factories with a production capacity of over 75 t/d led to the estimated consumption of electricity, expressed in kWh/t of product, and of thermal energy, expressed in kWh/t and MJ/t shown in Table 3.64.

| Estimated energy consumption            | Range                                 |
|---|---------------------------------------|
| Electricity                             | 140 - 220 kWh/t                       |
| Thermal energy (measured at the boiler) | 0.417 – 0.527 kWh/t<br>1.5 – 1.9 MJ/t |

**Table 3.64: Energy consumption in the Italian pasta industry**  
[117, CIAA-UNAFPA, 2002, 150, Unione Industriali Pastai Italiani, 2002]

### 3.3.7 Starch

Starch is manufactured from basically three major raw materials in Europe: maize, wheat and potatoes. The specific average consumptions are as follows: 1.85 tonnes of maize, 2.35 tonnes of wheat or 6.6 tonnes potatoes are used to produce 1 tonne starch [115, CIAA-AAC-UFE, 2002, 152, Austria, 2002].

#### 3.3.7.1 Water consumption

Water consumption also depends on the starch and starch derived products produced on a particular site. The water consumption also differs according to the raw material used. Due to the higher water content of potatoes, the potato starch process requires less water than the cereal starch process. During the last 20 years, the starch industry has realised substantial savings, up to 20 %, in fresh water consumption through process integrating measures, internal recycling of process water and optimisation of the cooling water system. Nevertheless, due to product applications, e.g. food and pharmacy, and to quality requirements, process water recycling is not always possible. Table 3.65 shows the water consumption in the starch sector.

| Raw material | Water consumption<br>(m <sup>3</sup> /t raw material used) |     |
|--------------|--|-----|
|              | Min  | Max |
| Maize        | 1.7  | 3   |
| Wheat        | 1.7  | 2.5 |
| Potato       | 0.7  | 1.5 |

**Table 3.65: Water consumption in the starch industry**  
[115, CIAA-AAC-UFE, 2002]

#### 3.3.7.2 Waste water

Specific waste water discharge from starch production in Austria is at 1.4 m<sup>3</sup>/t of processed potato, i.e. average of a processing campaign, 1.8 m<sup>3</sup>/t of processed maize, i.e. yearly average, and 2.0 m<sup>3</sup>/t of processed wheat, i.e. yearly average [152, Austria, 2002].

#### 3.3.7.3 Air emissions

Dust emission from starch driers is between 10 – 80 mg/Nm<sup>3</sup> [115, CIAA-AAC-UFE, 2002].

#### 3.3.7.4 Solid output

There are many factors that affect the amount of sludge after waste water treatment. It is reported that the type and the efficiency of the manufacturing process used is the most important. Also, practically no sludge is generated if there is anaerobic waste water treatment before discharging to the MWWTP. Some by-products, e.g. gluten produced in starch manufacturing, can be used in other food or animal feed processes, or sent for landspreading. Table 3.66 shows the solid outputs from the starch industry.

| Parameter                                     | Solid output<br>(kg/t raw material used) |     |
|---|--|-----|
|   | Min                                      | Max |
| Stones*                                       | 1  | 10* |
| Soil  | 8  | 60* |
| Organic matters                               | 0.5                                      | 4   |
| Sand*   | 1.5                                      | 7*  |
| Waste water sludge**                          | 0  | 3   |
| *The highest values are for potato processing |  |     |
| **Data are expressed in dry substance         |  |     |

**Table 3.66: Solid outputs from the starch industry**  
[115, CIAA-AAC-UFE, 2002]

### 3.3.7.5 Energy

The energy consumption depends on the starch and starch derived products produced on the site, i.e. on the techniques and processes involved in the starch production and co-products management. However, the main use of energy in starch production is thermal energy for the evaporation and drying processes. The energy used to produce starch slurry is low in comparison to the final production of dry products. More energy is consumed at sites where evaporation and/or drying processes are used for co-products such as fibre, solubles and proteins than at sites where solubles are landspread and fibre is sold as wet cattle feed. The general consumption of energy in the starch sector is given in the Table 3.67.

| Energy            | Raw material              | Min | Max  |
|-------------------|---------------------------|-----|------|
|                   | (kWh/t raw material used) |     |      |
| Electrical energy | Maize                     | 100 | 200  |
|                   | Wheat                     | 200 | 500  |
|                   | Potato                    | 40  | 80   |
| Thermal energy    | Maize                     | 200 | 500  |
|                   | Wheat                     | 800 | 1300 |
|                   | Potato                    | 50  | 250  |

**Table 3.67: Energy consumption in the starch industry**  
[115, CIAA-AAC-UFE, 2002]

### 3.3.8 Sugar

Most of the information in this sector comes from the “Guide to Establishing BAT in the Sugar Industry; Comité Européen des Fabricants de Sucre (June 2001)” [61, CEFS, 2001], unless otherwise stated.

#### 3.3.8.1 Sugar beet

##### 3.3.8.1.1 Water consumption

The water requirement for fluming is about 500 – 800 % of the amount of beet. For washing, 150 – 200 % is needed, and for a single stone catcher 70 – 100 % water is needed based on the amount of beet. The mechanically clarified water is re-used for fluming and washing, thus only 25 – 30 % beet based industrial water needs to be added during the last rinsing of the beets after washing.

Smaller losses are caused by evaporation of the cooling water and by discharging by-products and wastes containing water. However, the root body consists of about 75 – 78 % water, therefore, the beets carry sufficient water into the processing, which accumulates as condensate. Thus, an installation producing sugar is a net water producer, because the water contained initially in the beet becomes available as surplus cooling water [134, AWARENET, 2002].

While the overall water used is about 15 m<sup>3</sup>/t sugar beet processed, the consumption of fresh water is 0.25 – 0.4 m<sup>3</sup>/t sugar beet processed, or even less in modern sugar factories. Water consumption depends on the activities of each installation, e.g. more water is consumed in an installation that extracts and refines sugar beet, than one that does only one of those activities. In Austria, the consumption of water is of 1.5 m<sup>3</sup>/t of sugar beet processed, equivalent to 9 m<sup>3</sup>/t produced sugar, was reported [152, Austria, 2002]. Table 3.69 shows the water consumption in Danish sugar factories.

| Parameter  | Specific value<br>per tonne of beet processed |                                       | Specific value<br>per tonne of sugar produced |                                       |
|--|---|---------------------------------------|---|---------------------------------------|
|  | Average                                       | Range                                 | Average                                       | Range                                 |
| Water (m <sup>3</sup> )                              | 0.37  | 0.23 <sup>a</sup> – 0.50 <sup>b</sup> | 2.39  | 1.56 <sup>a</sup> – 3.21 <sup>b</sup> |
| <sup>a</sup> Excluding cooling water (two factories) |   |                                       |   |                                       |
| <sup>b</sup> Including cooling water (two factories) |   |                                       |   |                                       |

**Table 3.68: Water consumption in Danish sugar factories**  
[139, Nielsen E.H. Lehmann, 2002]

### 3.3.8.1.2 Waste water

Sugar beet is 75 % water, and the extraction process, by definition, aims to release a high proportion of water contained in the beets. Approximately half of this water is lost due to evaporation or inclusion in various product streams. The remainder is, after usage for washing and fluming, a source of high strength waste water.

The beets are floated through the cleaning stage where stones, weeds and other gross contaminants are removed. The transport water pumped off with the soil sludge can be up to 70 % of the beet. It has a high organic contamination due to the soil and sugar from damaged beets. Its COD is 5000 – 20000 mg/l.

The beets then enter the installation, where they are washed before being sliced into cosettes to maximise the surface area for the extraction process. The condensate from the evaporation and crystallisation stages is partly used as process water in several process stages, including beet washing. Process waste water is deemed to be the excess condensate from the concentration and crystallisation stages. This surplus condensate is high in ammonia and relatively low in COD content. Waste water with high BOD levels is produced in large volumes [13, Environment Agency of England and Wales, 2000] and is cleaned in a WWTP.

### 3.3.8.1.3 Solid output

During the reception and fluming of the sugar beet, soil, stones, sand and vegetable matter, e.g. seeds, beet tails and leaves, are removed. The amount of the earth adhering to the beet may vary greatly depending on, e.g. the weather conditions during harvesting and the design and operation of the harvester. In the annual processing of 500000 tonnes of beets, an average of 60000 tonnes of soil accumulates [87, Ullmann, 2001]. The soil arriving at the installation is removed in settling ponds. The sediment may be re-applied to arable land or may be used for other purposes, such as horticulture or civil engineering works. The vegetable matter is separated from the fluming water for sale as animal feed or fertiliser.

The sugar content of the beets does not vary greatly, e.g. 18.4 % in Austria and 13.9 % in Greece [87, Ullmann, 2001]. The efficiency of sugar extraction is about 90 %. There are other substances either in the wastes or by-products, such as beet pulp. After sugar is taken out, the extracted beet pulp is pressed. The wet pulp may then be dried. Beet pulp is normally sold as sweet feed for cattle. Another by-product is carbonation lime. Juice purification is done using lime. It may be pressed and sold to de-acidify or balance the pH of soil.

Sugar beets contain some soluble non-sugar substances, 30 – 40 % of which are eliminated during purification of the juice with  $\text{Ca}^{2+}$  precipitable anions, pectins and proteins. The remainder is left in the juice and prevents the complete crystallisation of the sugar, leaving a final syrup, called molasses. This is the major single loss of sugar in the process. 10 – 18 % of the sugar content of the beet is in molasses. About 38 kg molasses per tonne of sugar beet is generated. Molasses is about 80 % solid material and 20 % water.

In a study of Danish sugar factories, approximately 49 % of the total production was reported to be primary products such as sugar, molasses and feed pills. While the remaining by-products such as lime, beet pulp and weeds were sold or re-used [139, Nielsen E.H. Lehmann, 2002].

Figure 3.16 shows a typical process flow diagram for a sugar beet processing installation and the production of waste water, wastes and by-products [134, AWARENET, 2002].

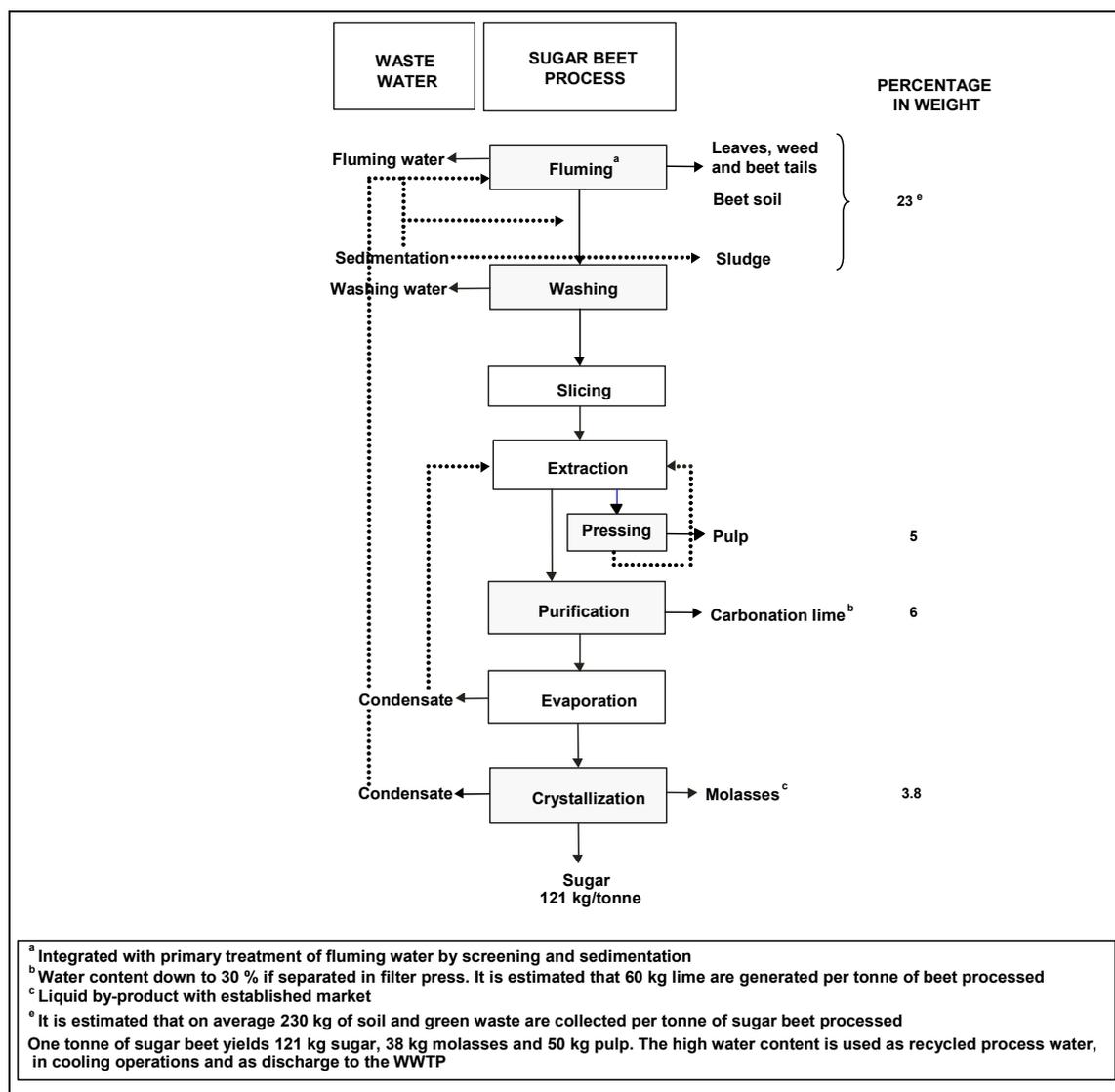


Figure 3.16: Type and amount of waste water, wastes and by-products from sugar beet processing [134, AWARENET, 2002]

### 3.3.8.1.4 Energy

Significant thermal energy is consumed for the evaporation and beet pulp drying. Electrical energy is needed for the pumps and for driving the centrifuges. According to CEFS, specific energy consumption was 31.49 kWh/100 kg beet in 1998 [159, CIAA-CEFS, 2003]. Table 3.69 shows the energy consumption in Danish sugar factories.

| Total energy (kWh) consumed                   |           |   |             |
|---|-----------|---|-------------|
| Specific value<br>per tonne of beet processed |           | Specific value<br>per tonne of sugar produced |             |
| Average                                       | Range     | Average                                       | Range       |
| 307   | 232 – 367 | 1987  | 1554 – 2379 |

**Table 3.69: Energy consumption in Danish sugar factories**  
[139, Nielsen E.H. Lehmann, 2002]

In a Greek study, a figure of 280 kWh/t is given for the electrical part of the energy consumption in sugar manufacturing [74, Greek Ministry for the Environment, 2001].

### 3.3.8.2 Cane sugar refining

The starting point is not sugar cane, but raw sugar, therefore less water is required than in sugar beet processing. The regeneration every 40 – 50 hours of the ion exchange resin cells used in the decolourisation process generates a difficult waste water as caustic brine is used as the regenerant [13, Environment Agency of England and Wales, 2000]. There may be excess condensate and sweet water although these can be eliminated (see Section 4.7.7.3). Waste water is generated from the steam cleaning of the bulk road tankers used to transport liquid sugar products.

### 3.3.9 Coffee

See extraction in Section 3.2.9, roasting in Section 3.2.39 and drying in Section 3.2.44.

### 3.3.10 Drinks

This section includes the production of ethyl alcohol by fermentation, manufacture of wine from grapes and from concentrated grape must, manufacture of fruit wines and other fermented fruit drinks, manufacture of cider and perry, manufacture of distilled alcoholic drinks, manufacture of soft drinks, and production of mineral waters, if this is carried out together with another activity covered by IPPC Directive. The manufacture of fruit juices and beer are discussed in Sections 3.3.3 and 3.3.11.

#### 3.3.10.1 Water consumption

Water consumption is in the range of 6 – 14 m<sup>3</sup>/m<sup>3</sup> product. In breweries, water is mainly used for mashing, heat transfer and cleaning operations. Water consumption for modern breweries generally ranges from 0.4 – 1 m<sup>3</sup>/hl.

#### 3.3.10.2 Waste water

The major issue in this sector is waste water generation. Some typical waste water production figures for the soft drinks sector are shown in Table 3.70.

| Product                 | Specific waste water discharge<br>(m <sup>3</sup> /m <sup>3</sup> of product) |
|-------------------------|---|
| Bottled waters          | 0.8   |
| Fruit juices            | 1.5   |
| Carbonates/dilutables   | 1.4   |
| Carbonates/fruit juices | 3.6   |

**Table 3.70: Average specific waste water discharges**  
[51, Envirowise (UK), 1998]

Processes for the manufacture of different drinks have common sources of waste water, including the following:

- cleaning of installation and equipment, and of containers, e.g. bottles, cans and casks
- pasteurisation of food in containers
- floor cleaning
- once-through cooling water or bleed from closed-circuit cooling systems
- boiler blowdown
- backwash from water treatment systems
- “chase” water purged from pipework between uses.

The preparation and cleaning of equipment is the largest source of waste water in this sector. The cleaning of fermenter vessels in particular is a major source of COD/BOD load and SS. Proprietary products used in the cleaning process, e.g. clay, disinfectants, detergents and disinfection agents, contribute to the waste water loadings. Dilute solutions of peracetic acid, a widely used disinfection agent, have a COD of approximately 1000 mg/l. An example installation from this sector changed the lubricant they used on their conveyors and reduced soap usage by 75 %. This led to a substantial COD reduction from discharges associated with the soap. In addition to these point sources, overflowing vessels and tanks often make a significant contribution to the waste water strength.

### 3.3.10.2.1 Wine

Waste water is generated in nearly all process steps, e.g. cleaning of containers, reactors and filters. The highest concentrated waste water is produced during fermentation, fining and ageing/racking due to the washing out of the sediments, marcs and lees. The semi-solid fractions can be separated for further dewatering, drying, processing or disposal rather than being washed with water, due to their high organic load. If solids from fining and racking are not separated, the waste water is highly contaminated and has extremely high BOD values of up to 500000 mg/l. Therefore, it is essential to recover the waste water components at source by filtration, centrifugation or sedimentation, so that they do not enter the WWTP. Wine bottles are cleaned before filling, and consequently washing water enters the WWTP or is recycled.

Even after the recovery process, the waste water shows an acidic character (pH 4 – 6) except when caustic solutions are used in the elimination of tartrate or during the conditioning of bottles. The most polluting waste water during wine production is generated during the fermentation and racking (especially first racking) operations. Average waste water composition is shown in Table 3.71.

|  | Fermentation |          |          | Ageing/racking |          |          | Barrel cleaning |
|--|--------------|----------|----------|----------------|----------|----------|-----------------|
|  | Cellar 1     | Cellar 2 | Cellar 3 | Cellar 1       | Cellar 2 | Cellar 3 |                 |
| pH   | 4.86         | 4.61     | 6.17     | 3.71           | 3.90     | 3.70     | 4.30            |
| Conductivity ( $\mu\text{S}/\text{cm}$ )                 | 893          | 641      | 531      | 1452           | 1377     | 1938     | 863             |
| COD ( $\text{mgO}_2/\text{l}$ )                          | 5249         | 2286     | 5925     | 22428          | 16210    | 66986    | 2401            |
| TSS ( $\text{mg}/\text{l}$ )                             | 444          | 452      | 205      | 4700           | 4490     | 31700    | 18              |
| TKN ( $\text{mgN}/\text{l}$ )                            | 51.5         | 40.9     | 35.9     | 239            | 279      | 1288     | 51.8            |
| N-NH <sub>4</sub> <sup>+</sup> ( $\text{mgN}/\text{l}$ ) | 7.86         | 7.28     | 13.1     | 34.3           | 33.1     | 154      | 11.2            |
| P-PO <sub>4</sub> <sup>3-</sup> ( $\text{mg}/\text{l}$ ) | 13.6         | 10.6     | 10.6     | 21.2           | 26.6     | 101      | 1.10            |
| BOD <sub>5</sub> ( $\text{mgO}_2/\text{l}$ )             | 3000         | 1900     | 3000     | 6000           | 9000     | 42500    | 1250            |

**Table 3.71: Waste water characteristics in processes of a red winery**  
[134, AWARENET, 2002]

### 3.3.10.2.2 Cider and perry

The major sources of waste water are the cooling water system, which serves the condensers and fermentation tanks, and the residues (vinasses) from the distillation towers. There are two main processes which generate waste water in cider and perry manufacturing installations, i.e. the production of the final product from juice, and the milling of fruit.

The production of the final product occurs all year round, whereas the milling of fruit is dictated by the harvesting of the fruit. Waste water from the production of the final product is generally generated from cleaning water; waste product, which is kept to a minimum and spillages from storage areas. During the milling season, the waste water volumes and strengths increase significantly. The main sources of waste water during this period are transport water used in conveying the fruit through the process, surplus evaporator water from juice concentrating, and general cleaning water.

The transport water can often be recycled, however, this waste water is highly polluted. Towards the middle of the milling season, flows and loads increase due to the quantity of fruit entering an installation. Towards the end of the milling season the volume of waste water decreases, however, the BOD and solids content of the waste water increases due to the deteriorating quality of the fruit being received.

### 3.3.11 Brewing

Beer is a fermented drink with a relatively low alcohol content made from various types of malt and grain. Malted barley predominates but malted wheat, maize or other grains, or sugar and syrups may also be used. Although there are installations where malt is also produced at the same premises, consumption and emission levels for malt production are reported in Section 3.2.26.

Breweries use significant amounts of water and energy and produce waste water and solid residues. Figure 3.17 shows the typical consumption and emission levels for German breweries. Note that capacity/output of breweries is usually expressed in hectolitres (hl) not in cubic metres (m<sup>3</sup>) of beer.

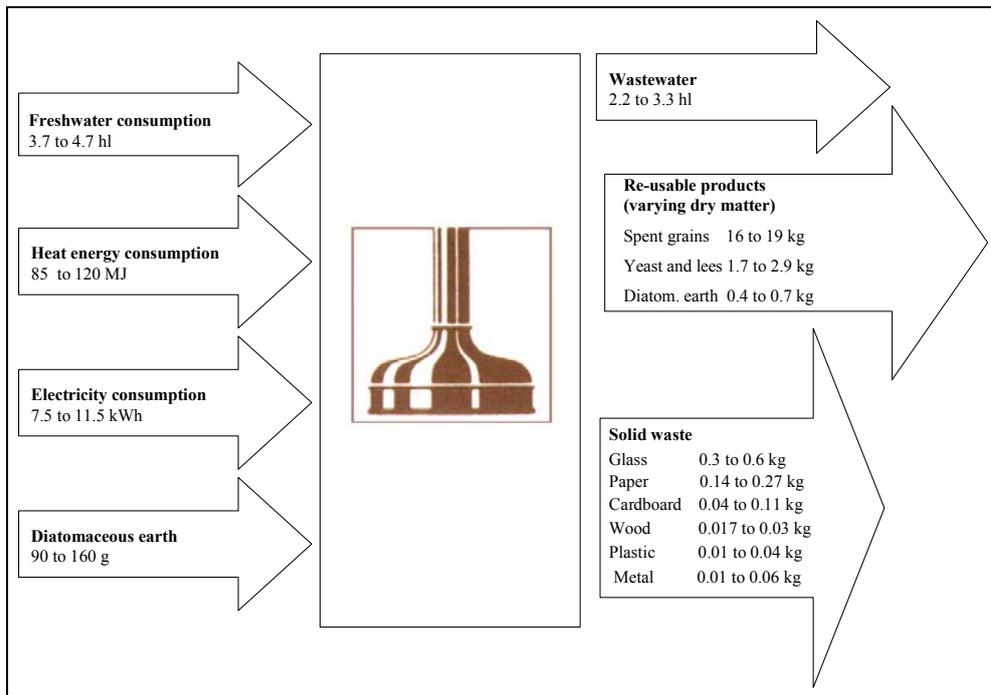


Figure 3.17: Input and output figures for large German breweries (capacity over 1 million hl beer) per hl of beer sold [65, Germany, 2002]

### 3.3.11.1 Water consumption

Water consumption for modern breweries generally ranges from 0.4 to 1 m<sup>3</sup>/hl of beer produced. An example Finnish brewery reported an average water consumption of 0.32 m<sup>3</sup>/hl [199, Finland, 2003]. Water consumptions for individual process stages, as reported for the German brewing industry, are shown in Table 3.72.

| Department  | Specific water consumption<br>(m <sup>3</sup> /hl beer produced) |              |              |              |
|---|--|--------------|--------------|--------------|
|   | Measured**   |              | Literature   |              |
|   | from   | to           | from         | to           |
| Brewhouse   | 0.130  | 0.236        | 0.174        | 0.26         |
| Cold storage  |  |              | 0.11         | 0.24         |
| Fermentation cellar   | 0.032  | 0.053        | 0.04         | 0.08         |
| Storage cellar  | 0.024  | 0.067        | 0.01         | 0.06         |
| Filtering cellar  | 0.031  | 0.109        | 0.01         | 0.076        |
| Bottling cellar   | 0.059  | 0.163        | 0.09         | 0.098        |
| Cask cellar   | 0.013  | 0.061        | 0.01         | 0.12         |
| Miscellaneous*  | 0.20   | 0.204        | 0.026        | 0.397        |
| <b>TOTAL PROCESS</b>  | <b>0.489</b>   | <b>0.893</b> | <b>0.470</b> | <b>1.331</b> |
| *Estimates  |  |              |              |              |
| **Measurements by Heidemann, Rosenwinkel and Seyfried (1990 to 1992) or brewery figures |  |              |              |              |

**Table 3.72: Water consumption for different brewery processes [65, Germany, 2002]**

The water consumption figure varies depending on the type of beer, the number of beer brands, the size of brews, the existence of a bottle washer, how the beer is packaged and pasteurised, the age of the installation, the system used for cleaning and the type of equipment used. If an on-site well is used, the water may require treatment before use, during which losses of up to 30 % may occur. Bottling consumes more water than keggering. Consumption levels are high for once through cooling systems and/or losses due to evaporation in hot climates.

### 3.3.11.2 Waste water

The waste water discharge is equal to the water supply minus the produced beer, the evaporated water in the brewery and utility plants, and the water present in the by-products and solid waste. It is reported that in Austria 0.26 – 0.6 m<sup>3</sup> of waste water is produced per hectolitre of beer. It is reported that in modern breweries 0.3 – 0.9 m<sup>3</sup> of waste water is produced per hectolitre of beer. An example Finnish brewery reported an average waste water production of 0.24 m<sup>3</sup>/hl [199, Finland, 2003]. Table 3.73 shows waste water production in different brewing processes.

| Department  | Specific waste water volume<br>(m <sup>3</sup> /hl beer produced) |              |                |                |
|---|---|--------------|----------------|----------------|
|   | Measured*   |              | Literature     |                |
|   | from  | to           | from           | to             |
| Brewhouse/cold storage  | 0.024   | 0.063        | 0.010<br>0.008 | 0.114<br>0.050 |
| Fermentation cellar   | 0.005   | 0.021        | 0.0012         | 0.070          |
| Storage cellar  | 0.005   | 0.013        | 0.0014         | 0.030          |
| Filtering cellar  | 0.019   | 0.059        | 0.0070         | 0.090          |
| Bottling cellar   | 0.036   | 0.068        | 0.070          | 0.280          |
| Cask cellar   | 0.008   | 0.037        | 0.0053         | 0.067          |
| Miscellaneous   | 0.020   | 0.204        | -              | -              |
| <b>Total process</b>  | <b>0.117</b>  | <b>0.465</b> | <b>0.1029</b>  | <b>0.701</b>   |
| * Measurements by Heidemann, Rosenwinkel and Seyfried (1990 – 1992) |   |              |                |                |

**Table 3.73: Waste water production in different brewery processes [65, Germany, 2002]**

The waste water is very variable and the pollution load of the different steps do not follow the volumes throughput, e.g. bottle cleaning produces a high amount of waste water but with only a low organic load, while waste water from fermentation and filtering account for only about 3 % of the total waste water volume but 97 % of the BOD load [140, World Bank (IBRD), et al., 1998]. Organic pollution in waste water mainly comes from the following sources:

- brewers grains
- yeast and surplus yeast
- trub
- weak wort discharge
- emptying and rinsing of water from kettles
- emptying of process tanks
- pre- and after-runs from diatomaceous earth filtration and filling
- chase water from process pipes
- rejected beer in the packaging area
- returned beer
- breakage of bottles in the packaging area
- ancillary materials used in the packaging area
- conveyor lubrication
- label glue.

SS in the waste water originate from the discharge of by-products, diatomaceous earth, e.g. kieselguhr, and possible label pulp from the bottle cleaner. Nitrogen originates mainly from detergents used for tank cleaning, from the malt and from additives. Phosphorus may come from the cleaning agents used. Large variations in pH may occur due to the use of acids and caustic for the cleaning of process equipment and returnable bottles. Heavy metals are normally present in very low concentrations. Wear of the machines, especially conveyors in packaging lines, may be sources of nickel and chromium. Table 3.74 shows the characteristics of untreated waste water from breweries. In terms of pollution load, Table 3.75 shows the ranges valid for modern breweries.

| Parameter        | Unit | Range       |
|------------------|------|-------------|
| BOD <sub>5</sub> | mg/l | 1000 – 1500 |
| COD              | mg/l | 1800 – 3000 |
| Suspended solids | mg/l | 10 – 60     |
| Total nitrogen   | mg/l | 30 – 100    |
| Total phosphorus | mg/l | 30 – 100    |
| pH               | –    | 3 – 13      |

**Table 3.74: Untreated waste water characteristics for breweries** [65, Germany, 2002, 136, CBMC - The Brewers of Europe, 2002, 140, World Bank (IBRD), et al., 1998]

| Parameter                  | Unit  | Range     |
|----------------------------|---|-----------|
| Water consumption          | hl water/hl beer sold                               | 4 – 10    |
| Waste water generation     | hl water/hl beer sold <b>less</b> water consumption | 1.3 – 1.8 |
| COD                        | kg/hl beer sold                                     | 0.8 – 2.5 |
| COD/BOD <sub>5</sub> ratio | –   | 1.5 – 1.7 |
| Total suspended solids     | kg/hl beer sold                                     | 0.2 – 0.4 |

**Table 3.75: Waste water and pollution generated in breweries** [136, CBMC - The Brewers of Europe, 2002]

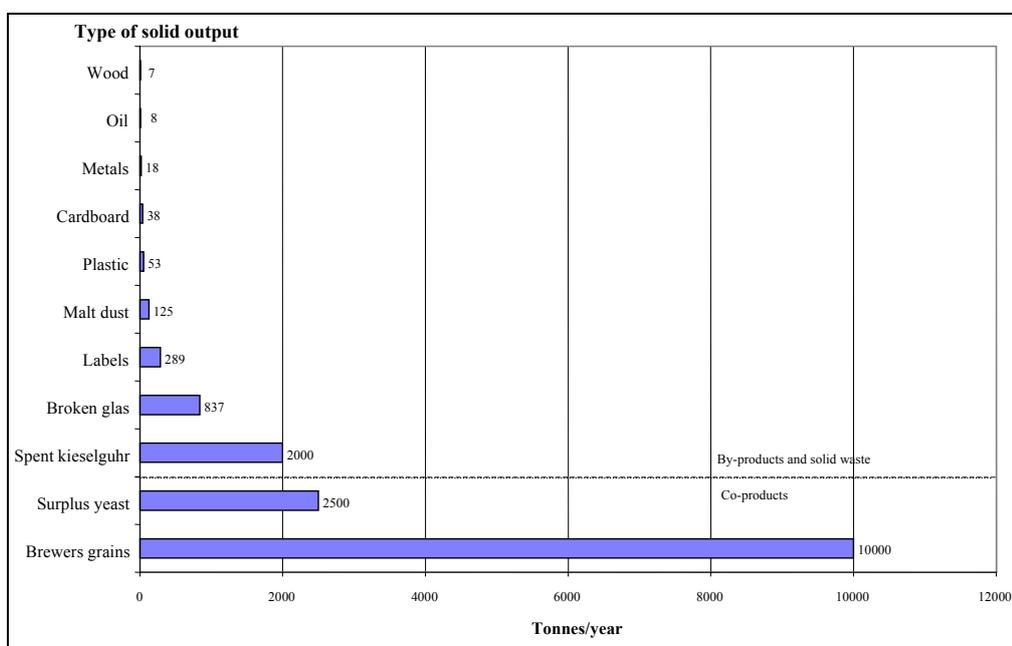
### 3.3.11.3 Air emissions

Apart from the emissions to air from energy generation processes, the main potential emission sources are dust from material intake and transport of raw materials, i.e. grains, and filtration aids, i.e. kieselguhr. Ammonia from cooling operations may be accidentally released.

The largest source of odour emissions is the evaporation from wort boiling. Other sources are waste water treatment, storage and handling of co-products and by-products, oil storage, ventilation of beer cellars and packaging lines and air emissions from the boiler house.

### 3.3.11.4 Solid output

Solid materials enter the brewery in the form of raw and ancillary materials. Solid materials leave the brewery as co-products such as brewers grains and surplus yeast, primary and secondary packaging material, and other solid waste. Generally, only a very small amount of hazardous waste is produced, e.g. spent laboratory chemicals and batteries. Major co-product, by-product and solid waste fractions are identified in the example shown in Figure 3.18. The generation of co-product, by-product and solid waste is quantified for a brewery that produces one million hectolitres of beer per year. The example installation produces beer bottled mainly in returnable bottles, and uses plastic crates. The generation of flue-gas and waste water treatment residuals are not considered.



**Figure 3.18: Co-product, by-product and solid waste quantities from a 1 million hl beer/yr brewery [136, CBMC - The Brewers of Europe, 2002]**

Husk and malt grits may be mixed into brewers grains which are used in the production process. Surplus yeast, brewers grains, trub from the whirlpool and husk and malt grits may be used as animal feed. Yeasts are also used in cosmetics, pharmaceuticals and spreads. Spent diatomaceous earth, i.e. kieselguhr, can be used in the cement industry, broken glass may be re-used for glass manufacturing. Label pulp from cleaning the returnable bottles, cardboard and paper wastes may be re-used in the paper industry. Plastics and metal from hop cans and replacement equipment may be recycled.

## 3.3.11.5 Energy

Breweries need both electrical and heat energy. Combined heat and power generation is in use in some facilities. Depending on availability, price and legal requirements, different fuels such as coal, oil or gas are used. Table 3.76 gives details on the energy, heat and electricity consumptions in some German breweries.

| Year | Heat                    |      |       |       | Electrical Power        | Beer Output            | Specific |          |
|------|-------------------------|------|-------|-------|-------------------------|------------------------|----------|----------|
|      | Coal                    | Oil  | Gas   | Total |                         |                        | Heat     | Power    |
|      | (x 10 <sup>3</sup> kWh) |      |       |       | (x 10 <sup>6</sup> kWh) | (x 10 <sup>6</sup> hl) | (kWh/hl) | (kWh/hl) |
| 1997 | 157                     | 929  | 2992  | 4078  | 1.2                     | 114.8                  | 35.5     | 10.4     |
| 1998 | 150                     | 846  | 2943  | 3939  | 1.2                     | 111.7                  | 35.3     | 10.6     |
| 1999 | 162                     | 789  | 2956  | 3907  | 1.2                     | 112.8                  | 34.6     | 10.4     |
| 2000 | 150                     | 683  | 2809  | 3642  | 1.2                     | 110.4                  | 33.0     | 10.5     |
|      | (x 10 <sup>3</sup> MJ)  |      |       |       | (MJ/hl)                 |                        |          |          |
| 1997 | 565                     | 3345 | 10771 | 14681 |                         |                        | 127.9    |          |
| 1998 | 541                     | 3046 | 10595 | 14182 |                         |                        | 127.0    |          |
| 1999 | 583                     | 2841 | 10642 | 14066 |                         |                        | 124.7    |          |
| 2000 | 540                     | 2458 | 10113 | 13111 |                         |                        | 118.7    |          |

**Table 3.76: Energy consumption of German breweries with more than 20 employees [65, Germany, 2002]**

A brewery without a sophisticated heat recovery system consumes about 27.78 – 55.55 kWh/hl beer (100 - 200 MJ/hl) [136, CBMC - The Brewers of Europe, 2002]. The main heat consuming process steps are mashing, wort boiling, generation of hot liquor, CIP, sterilising, bottle/keg cleaning and pasteurising. Heat consumption for some departments is given in Table 3.77.

| Department/<br>process                         | Minimum       | Mean  | Maximum | Literature <sup>1</sup> | Measured <sup>2</sup> |
|--|---------------|-------|---------|-------------------------|-----------------------|
|  | figure        |       |         | range                   |                       |
|  | (MJ/hl beer)  |       |         | (MJ/hl beer)            |                       |
| Brewhouse                                      | 87            | 92    | 121     | 84 – 113                | 50 – 80               |
| Bottling installation                          | 58            | 86    | 94      | 25 – 46                 | 38 – 58               |
| Kegging installation                           | 8             | 11    | 13      | 8 – 13                  |                       |
| Process water                                  | 3             | 4     | 8       | 4 – 8                   |                       |
| Service water                                  |               |       |         | 8 – 17                  |                       |
| Miscellaneous                                  |               |       |         | 33 – 46                 | 95                    |
| Total  | 156           | 193   | 236     | 162 – 243               | 183 – 233             |
|  | (kWh/hl beer) |       |         | (kWh/hl beer)           |                       |
| Brewhouse                                      | 24.17         | 25.56 | 33.61   | 23.33 – 31.39           | 13.89 – 22.22         |
| Bottling installation                          | 16.11         | 23.89 | 26.11   | 6.94 – 12.78            | 10.56 – 16.11         |
| Kegging installation                           | 2.22          | 3.06  | 3.61    | 2.22 – 3.61             |                       |
| Process water                                  | 0.83          | 1.11  | 2.22    | 1.11 – 2.22             |                       |
| Service water                                  |               |       |         | 2.22 – 4.72             |                       |
| Miscellaneous                                  |               |       |         | 9.17 – 12.78            | 26.39                 |
| Total  | 43.33         | 53.62 | 65.55   | 44.99 – 67.50           | 24.44 – 64.72         |
| <sup>1)</sup> 20000 to 500000 hl beer sold/yr  |               |       |         |                         |                       |
| <sup>2)</sup> 300000 to 500000 hl beer sold/yr |               |       |         |                         |                       |

**Table 3.77: Heat consumption for different brewery processes [65, Germany, 2002]**

The major consumers of electrical energy are the packaging area; cooling plant; compressed air plant; if applied, the carbon dioxide recovery plant; WWTP and air conditioning. Pumps, ventilators, drives, and electric lighting count for a large part of the electricity consumption, with about 8 – 12 kWh/hl in a brewery.

### 3.3.11.6 Noise

The main noise sources are transport within the brewery with lorries and forklifts, condensers and cooling towers.

### 3.3.11.7 Solid output

The majority of solid waste arises from packaging.

## 3.3.12 Citric acid

The process is described in Section 2.2.20. The major environmental issues are water pollution and the generation of solid wastes.

### 3.3.12.1 Water consumption

Specific water consumption is around 40 m<sup>3</sup> per tonne of installation citric acid production capacity.

### 3.3.12.2 Waste water

The waste water generated has high COD levels; compounds containing calcium and sulphur derived from precipitation and decomposition, and a high concentration of NH<sub>4</sub>-N from the raw material (molasses) and fermentation [151, Austrian contribution, 2002].

### 3.3.12.3 Solid output

The main solid wastes are the mycelium of the mould filtered from the fermentation broth, the gypsum generated during citric acid purification and the solid wastes produced during waste water treatment, i.e. anaerobic sludge and sulphur from biogas. Minor quantities of filtering aids are derived from polishing filtration. The solid wastes and by-products from citric acid fermentation are shown in Table 3.78.

| Solid waste and by-product                     | Unit                            | Value |
|--|---------------------------------|-------|
| Mycelium                                       | kg dry matter/<br>t citric acid | 100   |
| Gypsum (CaSO <sub>4</sub> x 2H <sub>2</sub> O) |                                 | 1000  |
| Waste water sludge from anaerobic pretreatment |                                 | 50    |
| Sulphur from desulphurisation                  |                                 | 3 – 4 |

**Table 3.78: Solid wastes and by-products in the citric acid fermentation process [151, Austrian contribution, 2002]**



## 4 BEI DER FESTLEGUNG VON BVT ZU BERÜCKSICHTIGENDE TECHNIKEN

Dieses Kapitel beschreibt Techniken, mit denen nach allgemeiner Ansicht in den im Rahmen dieses Dokuments beschriebenen Branchen ein hohes Maß an Umweltschutz erreicht werden kann. Es werden Managementsysteme, prozessintegrierte Techniken und Endbehandlungsverfahren („end-of-pipe“) berücksichtigt, wobei es allerdings bei der Suche nach optimalen Ergebnissen zu Überlappungen zwischen den drei Bereichen kommt.

Maßnahmen zur Vorsorge, Steuerung, Minimierung und Rückführung werden ebenso berücksichtigt wie die Wiederverwendung von Stoffen und Energie.

Die Techniken können einzeln oder in der Kombination vorgestellt werden, in der sie zur Erreichung der IVU-Ziele eingesetzt werden. In Anhang IV der IVU-Richtlinie sind allgemeine Vorgaben aufgeführt, die bei der Festlegung der BVT zu berücksichtigen sind. Die Techniken in diesem Kapitel 4 berücksichtigen mindestens eine dieser Vorgaben. Soweit möglich, wird eine einheitliche Struktur für die Beschreibung der einzelnen Techniken verwendet, damit sich diese einerseits besser vergleichen lassen und andererseits ihre Bewertung vor dem Hintergrund der in der Richtlinie gegebenen Definition einer BVT möglich wird.

Dieses Kapitel bietet keine abschließende Auflistung der Techniken. Es können weitere Techniken existieren oder entwickelt werden, die im Rahmen der BVT ebenso gültig sind.

Zur Beschreibung der einzelnen Techniken wird allgemein die in Tabelle 4.1 angegebene Struktur verwendet.

| Informationsart             | Art der enthaltenen Angaben   |
|-----------------------------|---|
| Beschreibung                | Technische Beschreibung der Technik   |
| Erreichbare Umweltvorteile  | Die wichtigsten von der Technik (Verfahren oder Vermeidung) betroffenen Umweltauswirkungen, einschließlich der erreichbaren Emissionswerte (normalerweise ein Bereich) und Effizienzleistung. Umweltvorteile der Technik im Vergleich zu anderen Techniken.   |
| Medienübergreifende Effekte | Durch die Umsetzung verursachte Nebenwirkungen und Nachteile für andere Medien. Umweltprobleme der Technik im Vergleich zu anderen Techniken.   |
| Betriebsdaten               | Leistungsdaten zu Emissionen (in Luft, Abwasser, Abfall) und Verbrauch (Rohstoffe, Wasser und Energie). Sämtliche sonstigen nützlichen Angaben zu Betrieb, Wartung und Steuerung der Technik, einschließlich Sicherheitsaspekten und Betriebseinschränkungen der Technik, Nutzleistung, Qualität usw. |
| Anwendbarkeit               | Zu berücksichtigende Faktoren für die Anwendung und Nachrüstung der Technik (z. B. verfügbarer Raum, verfahrensspezifisch).   |
| Wirtschaftlichkeit          | Angaben zu Kosten (Investition und Betrieb) und möglichen Einsparungen (z. B. geringerer Rohstoffverbrauch, Abfallgebühren), vorzugsweise bezogen auf die Kapazität der Technik.  |
| Anlass für die Umsetzung    | Gründe für die Umsetzung der Technik (z. B. geänderte gesetzliche Bestimmungen, Verbesserungen der Produktqualität)   |
| Beispielanlagen             | Angaben zu Anlagen, in denen die Technik eingesetzt wird.   |
| Referenzliteratur           | Literaturangaben zu ausführlicheren Informationen über die Technik.   |

**Tabelle 4.1: Gliederung der Angaben zu den Techniken, die bei der Festlegung der BVT berücksichtigt werden**

In diesem Dokument sind einige nachsorgende Techniken in dieses Kapitel aufgenommen worden, unabhängig davon, ob sie bei der Festlegung der BVT berücksichtigt wurden, z. B. in den Abschnitten 4.4 und 4.5.

Die beschriebenen Techniken zeigen, dass Vorsorge durch viele Möglichkeiten erreicht werden kann. Es können Produktionstechniken verwendet werden, die möglichst wenig umweltverschmutzend sind. Der Materialeinsatz kann dabei verringert und die Prozesse so geführt werden, dass die Produkte, die beispielsweise den Kundenanforderungen nicht entsprechen, wiederverwendet werden können. Die Managementpraktiken

lassen sich damit verbessern und bestimmte Substanzen können durch weniger gefährliche ersetzt werden. Dieses Kapitel gibt Informationen sowohl zu allgemeinen als auch zu spezifischen Techniken zur Vermeidung und Verminderung der Umweltverschmutzung, die in industriellem Maßstab umgesetzt wurden.

Das BVT-Merkblatt über Lagerung [95, EC, 2005] behandelt allgemeine Lagerungs- und Handhabungstechniken, weshalb diese im Allgemeinen nicht in das vorliegende Dokument aufgenommen wurden. Ausgenommen davon sind Techniken, die sich auf nahrungsmittelspezifische Fragen wie Lebensmittelsicherheit und Haltbarkeit beziehen.

Die Nahrungsmittelproduktion (im Englischen als „Food, Drink and Milk (FDM) Sector bezeichnet) ist so vielgestaltig, dass es unmöglich ist, alle Techniken zu beschreiben, die bei der Festlegung von BVT für sämtliche Vorgänge und unter allen denkbaren Umständen zu berücksichtigen sind. Es ist aber auch offensichtlich, dass es mehrere gute Techniken gibt, die in einem Teil dieses Sektors verwendet werden und sich auch auf andere übertragen lassen.

Dieses Kapitel ist folgendermaßen in sieben Hauptabschnitte unterteilt:

### Abschnitt 4.1 Allgemeine Techniken für die Nahrungsmittelproduktion

In diesem Abschnitt werden Techniken beschrieben, die allgemein in der Nahrungsmittelproduktion anwendbar sind, sich jedoch nicht auf einen bestimmten Arbeitsbereich beziehen. Manche gelten für Management und Steuerung von Anlagen insgesamt, z. B. die Durchführung von Schulungen, und andere können in einer Vielzahl von Arbeitsbereichen eingesetzt werden, z. B. Füllstandsmessungen.

### Abschnitt 4.2 Techniken, die in mehreren Bereichen der Nahrungsmittelproduktion anwendbar sind

In diesem Abschnitt werden Techniken beschrieben, die auf einzelne Arbeitsbereiche in manchen Branchen der Nahrungsmittelproduktion angewandt werden können, in anderen jedoch nicht. Die Techniken werden in derselben Reihenfolge vorgestellt, wie die Arbeitsbereiche und deren derzeitige Verbrauchs- und Emissionswerte in den Kapiteln 2 bzw. 3 beschrieben werden.

### Abschnitt 4.3 Reinigung

Die Hygiene hat in der Nahrungsmittelproduktion eine sehr hohe Priorität, da sie sich auf Produktsicherheit, -qualität und -haltbarkeit auswirkt und damit die Verschwendung von Einsatzstoffen und Produkten der Nahrungsmittelindustrie vermeidet. Es werden Techniken beschrieben, mit denen die Notwendigkeit regelmäßiger und effektiver Reinigungsvorgänge anerkannt und gleichzeitig auf die Minimierung von Umweltauswirkungen geachtet wird.

### Abschnitt 4.4 Techniken zur Minimierung von Emissionen in die Luft

In diesem Abschnitt werden Techniken zur Verringerung von Emissionen in die Umgebungsluft beschrieben. Viele der hier angeführten Techniken sind nachsorgende Maßnahmen zur Reduzierung von Emissionen, die bei der Anwendung prozessintegrierter Techniken technisch oder betriebstechnisch nicht verhindert werden können.

### Abschnitt 4.5 Nachsorgende Abwasserbehandlung

Sämtliche Anlagen der Nahrungsmittelindustrie erzeugen Abwasser. Viele Anlagen verfügen über eigene Kläranlagen, in denen entweder eine Vorklärung des Abwassers vor der Weiterleitung zur weiteren Behandlung in externe Kläranlagen oder eine Aufbereitung zwecks Wiederverwendung in der eigenen Anlage oder zur direkten Ableitung in die Umwelt vorgenommen wird. Im ersten Teil dieses Abschnitts werden allgemeine Techniken der Abwasserbehandlung beschrieben. Der zweite Teil enthält Informationen zur Abwasserbehandlung in einigen Branchen.

### Abschnitt 4.6 Unfallverhütung

In diesem Abschnitt werden Techniken zur Identifizierung, Bewertung und Einschränkung von Unfallrisiken und zur Minimierung von Umweltauswirkungen bei auftretenden Betriebsstörungen beschrieben.

### Abschnitt 4.7 Techniken, die in bestimmten Einzelbranchen anwendbar sind

In diesem Abschnitt werden Techniken unter den Überschriften der jeweiligen Branchen, in denen sie bekanntermaßen angewandt werden können, beschrieben. Die Techniken werden in derselben Reihenfolge vorgestellt wie die Angaben zu bestimmten Branchen in den Kapiteln 2 und 3.

Bei der Auswahl der beschriebenen Techniken wurde darauf geachtet, dass sie nicht mit den Anforderungen geltender gesetzlicher Bestimmungen zur Lebensmittelsicherheit kollidieren.

## 4.1 Allgemeine Techniken für die Nahrungsmittelproduktion

### 4.1.1 Umweltmanagement-Werkzeuge

#### Beschreibung

Üblicherweise lässt sich die beste Umweltleistung durch die Installation der besten Technologie und deren Betrieb in einer möglichst effektiven und effizienten Weise erzielen. Dem wird in der Definition von „Techniken“ in der IVU-Richtlinie Rechnung getragen, die diese als „sowohl die angewandte Technologie als auch die Art und Weise, wie die Anlage geplant, gebaut, gewartet, betrieben und stillgelegt wird“ versteht.

In IVU-Anlagen stellen Umweltmanagementsysteme (UMS) Werkzeuge dar, mit denen der Betreiber Fragen zu Planung, Bau, Wartung, Betrieb und Stilllegung auf systematische und nachvollziehbare Weise behandeln kann. Ein UMS umfasst die Organisationsstruktur, Zuständigkeiten, Verhaltensweisen, förmlichen Verfahren, Abläufe und Mittel für die Entwicklung, Umsetzung, Aufrechterhaltung, Überprüfung und Überwachung der Umweltpolitik. Am effektivsten und effizientesten sind Umweltmanagementsysteme, wenn sie inhärenter Bestandteil von Management und Betrieb der Anlage insgesamt sind.

In der Europäischen Union haben sich viele Organisationen entschieden, freiwillig ein Umweltmanagementsystem nach EN ISO 14001:1996 oder dem EU-Umwelt-Audit-System EMAS einzuführen. Das EMAS beinhaltet die Anforderungen an das Managementsystem nach EN ISO 14001, legt darüber hinaus jedoch Wert auf die Einhaltung von Rechtsvorschriften, Umweltbilanzen und die Einbeziehung der Mitarbeiter. Außerdem fordert es die externe Verifizierung des Managementsystems und die Validierung einer veröffentlichten Umwelterklärung (nach EN ISO 14001 ist die Eigenerklärung eine Alternative zur externen Verifizierung). Außerdem haben sich viele weitere Organisationen entschieden, nicht genormte UMS aufzubauen.

Während die zwei genormten Systeme (EN ISO 14001:1996 und EMAS) und auch die nicht genormten („benutzerdefinierten“) Systeme grundsätzlich die *Organisation* als die betrachtete Einheit sehen, verfolgt das vorliegende Dokument eine engere Sichtweise, indem es nicht sämtliche Aktivitäten einer Organisation, beispielsweise in Bezug auf Produkte und Dienstleistungen, einbezieht, da die durch die IVU-Richtlinie regulierte Einheit die *Anlage* (gemäß Definition in Artikel 2) ist.

Umweltmanagementsysteme (UMS) für IVU-Anlagen können folgende Bestandteile haben:

- (a) Festlegung einer Umweltpolitik
- (b) Planung und Festlegung von Zielsetzungen und Einzelzielen
- (c) Umsetzung und Durchführung von Verfahren
- (d) Überprüfung und Korrekturmaßnahmen
- (e) Überprüfung durch die Unternehmensleitung
- (f) Erstellung einer regulären Umwelterklärung
- (g) Validierung durch die zertifizierende Körperschaft oder einen externen UMS-Prüfer
- (h) Planungserwägungen zur Außerbetriebnahme der Anlage am Ende ihrer Lebensdauer
- (i) Entwicklung saubererer Technologien
- (j) betriebliche Kennzahlenvergleiche (Benchmarking).

Diese Bestandteile werden im Folgenden etwas ausführlicher erläutert. Detaillierte Informationen zu den Bestandteilen (a) bis (g), die alle im EMAS enthalten sind, finden sich in der unten angegebenen Literatur.

#### (a) Festlegung einer Umweltpolitik

Die Unternehmensleitung ist verantwortlich für die Festlegung einer Umweltpolitik für die Anlage und hat dafür Sorge zu tragen, dass diese:

- der Art, der Dimension und den Umweltauswirkungen der Tätigkeiten gerecht wird,
- eine Verpflichtung zur Verschmutzungsvermeidung und -überwachung enthält,
- eine Verpflichtung zur Einhaltung sämtlicher relevanter anwendbarer Umweltgesetze und -bestimmungen sowie anderer Anforderungen enthält, denen die Organisation verpflichtet ist,
- den Rahmen für die Festlegung und Überprüfung von Umweltzielsetzungen und -einzelzielen liefert,

- dokumentiert und allen Mitarbeitern vermittelt wird,
- der Öffentlichkeit und sämtlichen interessierten Parteien zugänglich ist.

(b) Planung, d. h.:

- Verfahren zur Identifizierung von Umweltaspekten der Anlage, damit diejenigen Tätigkeiten erkannt werden können, die eine erhebliche Auswirkung auf die Umwelt haben oder haben können, sowie zur laufenden Aktualisierung dieser Informationen
- Verfahren für die Identifizierung von und den Zugriff auf rechtliche und andere Vorschriften, denen die Organisation unterliegt und die auf die Umweltaspekte ihrer Tätigkeiten anwendbar sind
- Festlegung und Überprüfung dokumentierter Umweltzielsetzungen und -einzelziele, wobei die rechtlichen und anderen Vorschriften sowie die Standpunkte interessierter Parteien berücksichtigt werden
- Aufstellung und regelmäßige Aktualisierung eines Umweltmanagementprogramms, einschließlich der Festlegung von Verantwortlichkeiten sowie der Mittel und Wege und des Zeitrahmens für das Erreichen von Zielsetzungen und Einzelzielen für jede relevante Funktion und Ebene.

(c) Umsetzung und Durchführung von Verfahren

Es ist wichtig, über Systeme zu verfügen, mit denen gewährleistet ist, dass Verfahren bekannt sind, verstanden und eingehalten werden. Ein wirksames Umweltmanagement beinhaltet deshalb:

(i) Struktur und Zuständigkeiten

- Festlegung, Dokumentation und Mitteilung von Rollen, Zuständigkeiten und Befugnissen, wozu auch die Benennung eines bestimmten Verantwortlichen für das Management gehört.
- Bereitstellung von Mitteln, die für die Umsetzung und Steuerung des Umweltmanagementsystems unabdingbar sind, wozu auch Arbeitskräfte und spezielle Fertigkeiten, technologische und finanzielle Mittel zählen.

(ii) Schulung, Bewusstsein und Kompetenz

- Identifizierung von Schulungsbedarf, damit sichergestellt ist, dass sämtliche Mitarbeiter, deren Arbeit wesentlichen Einfluss auf die Umweltauswirkungen einer Aktivität haben, entsprechend geschult wurden.

(iii) Kommunikation

- Einrichtung und Pflege von Verfahren für die interne Kommunikation zwischen den verschiedenen Ebenen und Funktionen der Anlage einerseits und von Verfahren zur Dialogförderung mit externen interessierten Parteien andererseits, sowie von Verfahren zur Entgegennahme, Dokumentation und ggf. Bearbeitung von relevanten Mitteilungen externer interessierter Parteien.

(iv) Einbeziehung von Mitarbeitern

- Einbeziehung der Mitarbeiter in den Vorgang zur Erzielung eines guten betrieblichen Umweltschutzes durch entsprechende Beteiligung der Mitarbeiter, wie z. B. Vorschlagsbuchsystem, projektbasierte Gruppenarbeiten oder Umweltausschüsse.

(v) Dokumentation

- Erstellung und Pflege von aktuellen Informationen in elektronischer oder Papierform, mit denen die Kernelemente des Managementsystems und ihre Wechselwirkungen beschrieben und Hinweise auf verwandte Dokumentation gegeben werden.

(vi) Effiziente Prozesssteuerung

- Angemessene Steuerung der Prozesse in allen Betriebsphasen, d. h. während der Vorbereitungs- und Startphase, im Routinebetrieb, beim Herunterfahren und unter Ausnahmehbedingungen.
- Identifizierung der Schlüsselindikatoren für die Leistung und der Methoden zur Messung und Steuerung dieser Parameter (z. B. Durchfluss, Druck, Temperatur, Zusammensetzung und Menge).
- Dokumentation und Untersuchung von betrieblichen Ausnahmehbedingungen zur Identifizierung und anschließenden Behebung der Grundursachen zwecks Vermeidung von Wiederholungen (dies lässt sich durch eine „schuldzuweisungsfreie“ Atmosphäre erzielen, in der es wichtiger ist, eine Ursache zu erkennen, als Einzelnen die Schuld zu geben).

## (vii) Wartungsprogramm

- Erstellung eines strukturierten Programms für die Wartung auf Grundlage der technischen Beschreibungen der Geräte, Normen etc., sowie für das Versagen von Geräten und die sich daraus ergebenden Folgen.
- Unterstützung des Wartungsprogramms durch geeignete Dokumentationssysteme und diagnostische Tests.
- Eindeutige Zuweisung der Zuständigkeiten für die Planung und Durchführung von Wartungsarbeiten.

## (viii) Vorbereitung auf Notfälle und Reaktionen im Notfall

- Erstellung und Pflege von Verfahren zur Identifizierung von möglichen Unfall- und Notfallsituationen sowie zur Festlegung der Reaktionen darauf und zur Vermeidung und Verminderung etwaiger damit einhergehender Umweltauswirkungen.

## (d) Überprüfung und Korrekturmaßnahmen, d. h.:

## (i) Überwachung und Messungen

- Erstellung und Pflege dokumentierter Verfahren zur regelmäßigen Überwachung und Messung der Schlüsseleigenschaften des Betriebs und von Aktivitäten, die wesentliche Umweltauswirkungen haben können. Dazu gehören die Aufzeichnung von Informationen zur Verfolgung der erzielten Ergebnisse, relevante betriebliche Kontrollen und die Einhaltung der für die Anlage festgelegten Umweltzielsetzungen und -einzelziele (*siehe auch Referenzdokument zur Emissionsüberwachung*).
- Festlegung und Pflege eines dokumentierten Verfahrens zur regelmäßigen Bewertung der Einhaltung relevanter umweltrechtlicher Gesetze und Bestimmungen.

## (ii) Korrektur- und Vorbeugemaßnahmen

- Erstellung und Pflege von Verfahren zur Festlegung von Verantwortlichkeiten und Befugnissen für den Umgang mit und die Untersuchung von Nichteinhaltungen von Genehmigungsaufgaben, anderen rechtlichen Vorschriften, Zielsetzungen und Einzelzielen, Ergreifung von Maßnahmen zur Minderung etwaiger Auswirkungen und zur Initiierung und abschließenden Durchführung von Korrektur- und Vorbeugemaßnahmen, die der Größenordnung des Problems angemessen sind und im richtigen Verhältnis zur aufgetretenen Umweltauswirkung stehen.

## (iii) Unterlagen

- Festlegung und Pflege von Verfahren zur Identifizierung, Pflege und Ablage von lesbaren, identifizierbaren und nachverfolgbaren Umweltunterlagen, einschließlich Schulungsunterlagen sowie Revisions- und Prüfungsergebnissen.

## (iv) Revision

- Erstellung und Pflege eines oder mehrerer Programme und Verfahren für regelmäßige Revisionen des Umweltmanagementsystems, die Besprechungen mit dem Personal, Inspektionen der Betriebsbedingungen und der Geräte sowie die Prüfung von Unterlagen und Dokumentationen mit der Abfassung eines schriftlichen Berichts beinhalten. Diese Revisionen müssen neutral und objektiv von Mitarbeitern (interne Prüfung) oder externen Personen (externe Prüfung) durchgeführt werden. Die Programme und Verfahren müssen Umfang, Häufigkeit und Methoden für die Prüfungen sowie die Zuständigkeiten und Anforderungen für die Durchführung von Prüfungen und für die Ergebnisberichterstattung festlegen, damit festgestellt werden kann, ob das Umweltmanagementsystem planmäßig funktioniert und ordnungsgemäß umgesetzt und gepflegt wird.
- Abschluss der Prüfung bzw. des Prüfungszyklus in Intervallen von nicht mehr als drei Jahren, je nach Art, Umfang und Komplexität der Aktivitäten, der Bedeutung der damit einhergehenden Umweltauswirkungen, der Bedeutung und Dringlichkeit der in früheren Prüfungen festgestellten Probleme und der Vorgeschichte im Bereich von Umweltproblemen. Komplexere Aktivitäten mit bedeutenderen Umweltauswirkungen werden häufiger einer Prüfung unterzogen.
- Es müssen angemessene Mechanismen vorhanden sein, mit denen sichergestellt werden kann, dass die Ergebnisse der Prüfungen beachtet werden.

(v) Regelmäßige Bewertung der Einhaltung rechtlicher Bestimmungen

- Überprüfung der Einhaltung des geltenden Umweltrechts und des Status der Umweltgenehmigung(en) der Anlage.
- Dokumentation dieser Bewertung.

(e) Überprüfung durch die Unternehmensleitung, d. h.:

- Überprüfung des Umweltmanagementsystems durch die oberste Leitungsebene in von dieser festgesetzten Zeitabständen, damit die fortgesetzte Eignung, Angemessenheit und Effektivität des Systems sichergestellt ist.
- Sicherstellung der Erhebung der notwendigen Daten und Angaben, um der Leitung diese Bewertung zu ermöglichen.
- Dokumentation dieser Überprüfung.

(f) Erstellung einer regulären Umwelterklärung:

- Erstellung einer Umwelterklärung, in der besonderes Augenmerk auf die mit der Anlage erzielten Ergebnisse im Vergleich zu den jeweiligen Umweltzielsetzungen und -einzelzielen gelegt wird. Regelmäßige Erstellung dieser Erklärung – einmal jährlich oder weniger häufig, je nach Bedeutung der Emissionen, Abfallerzeugung usw. In der Erklärung wird der Informationsbedarf relevanter interessierter Parteien berücksichtigt; sie ist öffentlich zugänglich (z. B. in elektronischen Veröffentlichungen, Büchereien usw.).

Bei der Erstellung der Erklärung kann der Betreiber bestehende relevante Indikatoren für die Umweltleistung verwenden, muss dabei aber sicherstellen, dass die gewählten Indikatoren:

- i. die Leistung der Anlage genau einschätzen,
- ii. verständlich und unzweideutig sind,
- iii. einen Vergleich von Jahr zu Jahr erlauben, damit die Entwicklung der Umweltleistung der Anlage beurteilt werden kann,
- iv. einen Vergleich mit den zutreffenden nationalen, regionalen oder auf Branchen bezogenen Kennzahlen erlauben,
- v. einen Vergleich mit den zutreffenden behördlichen Anforderungen erlauben.

(g) Validierung durch die zertifizierende Körperschaft oder einen externen UMS-Prüfer:

- Die Überprüfung und Validierung von Managementsystem, Prüfungsverfahren und Umwelterklärung durch eine akkreditierte Zertifizierungsstelle oder einen externen UMS-Prüfer kann bei ordnungsgemäßer Durchführung die Glaubwürdigkeit des Systems erhöhen.

(h) Planungserwägungen zur Außerbetriebnahme der Anlage am Ende ihrer Lebensdauer

- Im Planungsstadium für eine neue Anlage sind die Umweltauswirkungen zu berücksichtigen, die von der endgültigen Außerbetriebnahme der Einheit ausgehen, da die Außerbetriebnahme durch vorausschauendes Denken einfacher, sauberer und kostengünstiger wird.
- Die Außerbetriebnahme ist möglicherweise mit Umweltrisiken für die Kontaminierung von Boden (und Grundwasser) und mit der Erzeugung großer Mengen festen Abfalls verbunden. Vorbeugende Techniken sind prozessspezifisch, aber allgemeine Erwägungen können folgende Punkte umfassen:
  - i. Vermeidung von unterirdischen Stoffeinlagerungen
  - ii. Ausstattung mit Eigenschaften, die den Abbruch erleichtern
  - iii. Auswahl leicht zu dekontaminierender Oberflächen
  - iv. Verwendung von Gerätekonfigurationen, durch die das Festsetzen von Chemikalien minimiert wird, und die das Abfließen oder das Abwaschen erleichtern.
  - v. Planung flexibler, eigenständiger Einheiten, durch die es möglich wird, die Anlage in Etappen zu schließen.
  - vi. falls möglich, Verwendung biologisch abbaubarer und wiederverwertbarer Materialien.

(i) Entwicklung saubererer Technologien:

- Der Umweltschutz sollte inhärentes Merkmal sämtlicher Verfahrensplanungen des Betreibers sein, da Techniken sowohl effektiver als auch kostengünstiger sind, wenn sie zum frühestmöglichen Zeitpunkt

eingepplant werden. Die Entwicklung saubererer Technologien kann beispielsweise durch F&E-Aktivitäten oder -Studien berücksichtigt werden. Alternativ zu internen Aktivitäten können Vorkehrungen getroffen werden, um auf dem Stand der Entwicklung zu bleiben und, wenn angebracht, Arbeiten an andere auf dem betreffenden Gebiet tätige Betreiber oder Forschungsinstitute zu vergeben.

(j) Betriebliche Kennzahlenvergleiche (Benchmarking), d. h.:

- Durchführung systematischer und regelmäßiger Vergleiche mit nationalen, regionalen oder auf Branchen bezogenen Kennzahlen, auch für Energieeffizienz-Aktivitäten und Energiesparmaßnahmen, für die Wahl der eingesetzten Produktionsmittel, Emissionen in die Luft und Einleitungen in das Wasser (beispielsweise unter Verwendung des Europäischen Schadstoffemissionsregisters, EPER), Wasserverbrauch und Abfallerzeugung.

### **Genormte und nicht genormte UMS**

Ein UMS kann in genormter oder nicht genormter („benutzerdefinierter“) Form bestehen. Die Einführung und Anwendung eines international anerkannten genormten Systems wie EN ISO 14001 (1996) kann einem UMS eine höhere Glaubwürdigkeit verleihen, insbesondere, wenn es einer ordnungsgemäß durchgeführten externen Überprüfung unterzogen wird. Das EMAS sorgt aufgrund des Kontakts mit der Öffentlichkeit durch die Umwelterklärung und den Mechanismus zur Sicherstellung der Einhaltung geltender umweltrechtlicher Bestimmungen für zusätzliche Glaubwürdigkeit. Nicht genormte Systeme können jedoch prinzipiell genauso effektiv sein, sofern sie ordnungsgemäß geplant und umgesetzt werden.

### Erreichbare Umweltvorteile

Bei der Umsetzung und Einhaltung eines UMS konzentriert sich die Aufmerksamkeit des Betreibers auf die Umweltbilanz der Anlage. Insbesondere die Pflege und Einhaltung eindeutiger Arbeitsanweisungen sowohl für den Normalbetrieb als auch für Ausnahmesituationen und die damit verbundenen Verantwortlichkeitsstrukturen sollten sicherstellen, dass die Einhaltung der Genehmigungsaufgaben und anderer Umweltzielsetzungen und -einzelziele für die Anlage jederzeit gewährleistet sind.

Umweltmanagementsysteme gewährleisten normalerweise die laufende Verbesserung der Umweltleistung der Anlage. Je schlechter der Ausgangszustand ist, desto wesentlichere kurzfristige Verbesserungen können erwartet werden. Wenn die Anlage bereits eine gute Umweltbilanz aufweist, hilft das System dem Betreiber den hohen Standard zu halten.

### Medienübergreifende Effekte

Umweltmanagementtechniken sind darauf ausgelegt, sich mit den Umweltauswirkungen insgesamt zu befassen, was dem integrierten Ansatz der IVU-Richtlinie entspricht.

### Betriebsdaten

Keine spezifischen Informationen gemeldet.

### Anwendbarkeit

Die oben beschriebenen Bestandteile lassen sich normalerweise auf alle IVU-Anlagen anwenden. Der Umfang (z. B. die gewählte Detailebene) und die Art des UMS (z. B. genormt oder nicht genormt) hängen im Allgemeinen von der Art, Dimension und Komplexität der Anlage und der Bandbreite ihrer möglichen Umweltauswirkungen ab.

### Wirtschaftlichkeit

Die genaue Ermittlung von Kosten und wirtschaftlichem Nutzen der Einführung und Pflege eines guten UMS ist schwierig. Im Folgenden werden einige Studien vorgestellt, die jedoch nur Beispiele darstellen, und deren Ergebnisse nicht immer kohärent sind. Sie sind möglicherweise nicht für alle Branchen in der gesamten EU repräsentativ und sollten daher mit Vorsicht behandelt werden.

In einer schwedischen Studie von 1999 wurden alle 360 ISO-zertifizierten und EMAS-registrierten Unternehmen in Schweden befragt. Die Antwortrate betrug 50 %. Die Studie kam unter anderem zu dem Schluss, dass:

- der Aufwand für die Einführung und den Betrieb eines UMS hoch, aber – außer im Falle von sehr kleinen Unternehmen – nicht übermäßig hoch ist und für die Zukunft ein Aufwandsrückgang zu erwarten ist
- eine bessere Koordination und Integration des UMS mit anderen Managementsystemen als eine Möglichkeit zur Kostensenkung gesehen wird

- die Hälfte aller Umweltzielsetzungen und -einzelziele innerhalb eines Jahres zu Kosteneinsparungen und/oder höheren Erträgen führen
- die größten Kosteneinsparungen durch niedrigere Ausgaben für Energie, Abfallbehandlung und Rohstoffe erzielt wurden
- die meisten Unternehmen der Ansicht sind, dass ihre Marktposition durch das UMS gestärkt wurde. Ein Drittel der Unternehmen berichtete über Ertragszuwächse durch das UMS.

In manchen Mitgliedsstaaten werden ermäßigte Überwachungsgebühren verlangt, wenn die Anlage zertifiziert ist.

Eine Reihe von Studien<sup>1</sup> zeigt, dass die Unternehmensgröße im umgekehrten Verhältnis zu den Kosten der Implementierung eines UMS steht. Ein ähnliches umgekehrtes Verhältnis besteht für den Amortisationszeitraum investierten Kapitals. Beide Faktoren bedeuten für die Implementierung eines UMS in kleinen und mittelständischen Unternehmen im Vergleich zu größeren Unternehmen ein ungünstigeres Kosten-Nutzen-Verhältnis.

Einer Schweizer Studie zufolge können sich die durchschnittlichen Kosten für den Aufbau und die Durchführung von ISO 14001 unterscheiden:

- bei Unternehmen mit 1 bis 49 Mitarbeitern: 64.000 CHF (44.000 EUR) für den Aufbau des EMS und 16.000 CHF (11.000 EUR) pro Jahr für dessen Betrieb
- bei Industriestandorten mit über 250 Mitarbeitern: 367.000 CHF (252.000 EUR) für den Aufbau des EMS und 155.000 CHF (106.000 EUR) pro Jahr für dessen Betrieb.

Diese Durchschnittszahlen stellen nicht unbedingt die tatsächlichen Kosten eines bestimmten Industriestandorts dar, da diese sehr stark abhängig sind von der Anzahl der entscheidenden Faktoren (Schadstoffe, Energieverbrauch, etc.) und der Komplexität der zu untersuchenden Probleme.

Eine jüngere deutsche Studie (Schaltegger, Stefan und Wagner, Marcus, *Umweltmanagement in deutschen Unternehmen – der aktuelle Stand der Praxis*, Februar 2002, S. 106) gibt die folgenden EMAS-Kosten für verschiedene Industriezweige an. Es ist auffällig, dass diese Zahlen deutlich unterhalb der oben genannten Angaben aus der Schweizer Studie liegen, was belegt, wie schwierig es ist, die Kosten eines UMS zu beziffern.

### Kosten für den Aufbau (EUR):

|              |   |        |
|--------------|---|--------|
| Mindestens   | - | 18.750 |
| Höchstens    | - | 75.000 |
| Durchschnitt | - | 50.000 |

### Kosten für die Validierung (EUR):

|              |   |        |
|--------------|---|--------|
| Mindestens   | - | 5.000  |
| Höchstens    | - | 12.500 |
| Durchschnitt | - | 6.000  |

Eine Studie des Unternehmerinstituts/Arbeitsgemeinschaft Selbständiger Unternehmer UNI/ASU von 1997 (*Umweltmanagementbefragung – Öko-Audit in der mittelständischen Praxis – Evaluierung und Ansätze für eine Effizienzsteigerung von Umweltmanagementsystemen in der Praxis*, Bonn) enthält Angaben zu den durchschnittlichen Einsparungen durch EMAS pro Jahr und der durchschnittlichen Amortisationsdauer. Darin wurden beispielsweise bei Implementationskosten von 80.000 EUR durchschnittliche Einsparungen von 50.000 EUR pro Jahr festgestellt, was einer Amortisationszeit von etwa anderthalb Jahren entspricht.

Externe Kosten im Zusammenhang mit der Systemverifizierung lassen sich anhand der Richtwerte des Internationalen Akkreditierungsforums (<http://www.iaf.nu>) schätzen.

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<sup>1</sup> Z. B. Dyllick and Hamschmidt (2000, 73) zitiert in Klemisch H. und R. Holger, *Umweltmanagementsysteme in kleinen und mittleren Unternehmen – Befunde bisheriger Umsetzung*, KNI Papers 01/02, Januar 2002, S. 15; Clausen J., M. Keil und M. Jungwirth, *The State of EMAS in the EU. Eco-Management as a Tool for Sustainable Development – Literature Study*, Institut für ökologische Wirtschaftsforschung (Berlin) und Ecologic – Institut für Internationale und Europäische Umweltpolitik (Berlin), 2002, S. 15.

Anlässe für die Umsetzung

Umweltmanagementsysteme können eine Vielzahl von Vorteilen bieten, z. B.:

- verbesserte Einsicht in Umweltaspekte des Unternehmens
- verbesserte Entscheidungsgrundlagen
- höhere Personalmotivation
- zusätzliche Gelegenheiten für Betriebskostenreduzierung und Produktqualitätsverbesserung
- verbesserte Umweltbilanz
- verbessertes Unternehmensimage
- geringere Haftungs-, Versicherungs- und Nichteinhaltungskosten
- größere Attraktivität für Mitarbeiter, Kunden und Investoren
- größeres Vertrauen der Aufsichtsbehörden und damit möglicherweise weniger Reglementierung
- verbessertes Verhältnis zu Umweltorganisationen.

Beispielanlagen

Die oben unter (a) bis (e) beschriebenen Punkte sind Bestandteile von EN ISO 14001 (1996) und dem EU-Umwelt-Audit-System (EMAS), wogegen die Punkte (f) und (g) nur im EMAS enthalten sind. Diese zwei genormten Systeme werden in einer Reihe von IVU-Anlagen eingesetzt. Innerhalb der Nahrungsmittelproduktion in der EU gibt es beispielsweise 342 beim EMAS registrierte Organisationen.

Im Vereinigten Königreich führte das Umweltamt für England und Wales (Environment Agency of England and Wales) 2001 eine Umfrage bei IVU-regulierten Anlagen durch. Sie ergab, dass von den antwortenden Betrieben 32 % ein ISO-14001-Zertifikat besaßen (was 21 % aller IVU-Anlagen entsprach) und 7 % EMAS-registriert waren. Alle Zementwerke im Vereinigten Königreich (etwa 20) sind ISO-14001-zertifiziert, und die Mehrzahl von ihnen ist EMAS-registriert. In Irland, wo die Einrichtung eines UMS (nicht notwendigerweise in genormter Form) für IVU-Genehmigungen gefordert wird, ist bei schätzungsweise 100 von etwa 500 genehmigten Anlagen ein UMS nach ISO 14001 im Einsatz. In den übrigen 400 Anlagen werden nicht genormte UMS benutzt.

Referenzliteratur

(Verordnung (EG) Nr. 761/2001 des europäischen Parlaments und des Rates vom 19. März 2001 über die freiwillige Beteiligung von Organisationen an einem Gemeinschaftssystem für das Umweltmanagement und die Umweltbetriebsprüfung (EMAS), Amtsblatt L 114 der Europäischen Union vom 24. April 2001, [http://europa.eu.int/comm/environment/emas/index\\_en.htm](http://europa.eu.int/comm/environment/emas/index_en.htm))

(EN ISO 14001:1996, <http://www.iso.ch/iso/en/iso9000-14000/iso14000/iso14000index.html>; <http://www.tc207.org>)

## 4.1.2 Optimierung des Betriebs durch Schulungen

Beschreibung

Wenn Mitarbeiter auf allen Ebenen, von der Unternehmensleitung bis zu den Arbeitern, die erforderliche Schulung und Einweisung in ihre Aufgaben erhalten, so kann dies zu einer Verbesserung der Prozesssteuerung und Minimierung von Verbrauchs- und Emissionswerten und Unfallrisiken beitragen. Diese Schulungen können mit firmeninternen oder externen Umweltberatern durchgeführt werden. Für das laufende Umweltmanagement des Prozesses können diese jedoch nicht verantwortlich sein. Probleme, die während des Routinebetriebs, des Anfahrens, Herunterfahrens, der Reinigung, der Wartung, unter Ausnahmebedingungen und bei Arbeiten außerhalb der Routine auftreten können, sollten mit abgedeckt werden. Anschließend kann die Unternehmensleitung in Zusammenarbeit mit den in der Produktion Beschäftigten die laufende Risikobewertung von Prozessen und Arbeitsbereichen sowie die Überwachung der Einhaltung von benannten Standards und Arbeitspraktiken durchführen.

Ein Schulungsangebot erfordert die Arbeitszeit des gesamten Personals für Informations-, Einweisungs-, Schulungs- und Überwachungsmaßnahmen sowie den Betrieb eines Bewertungsprogramms, damit der Schulungsbedarf und die Effektivität der Schulungen ermittelt werden können.

Erreichbare Umweltvorteile

Reduzierung des Verbrauchs, der Emissionswerte und des Unfallrisikos in der gesamten Anlage.

### Betriebsdaten

Es gibt zahlreiche Beispiele für Umweltvorteile, die durch einen mittels Schulungen optimierten Betrieb erzielt werden, einschließlich der Unfallverhütung. Beispiele sind:

- Vermeidung des Auslaufens beim Trennen von Rohren und Schläuchen, beispielsweise bei der Tankanlieferung von Milch, oder von Reinigungschemikalien wie ätzenden und organischen Lösemitteln wie z. B. Hexan in der Pflanzenölraffinierung.
- Vermeidung von Produktverlusten und Verschüttungen in Lagern durch angemessene Schulung von Arbeitskräften, z. B. von Gabelstaplerfahrern.
- Gewährleistung, dass Gefäße und Schläuche vor dem Trennen entleert werden.
- Die Ableitung übelriechender Flüssigkeiten unterhalb des Flüssigkeitspegels in ein Gefäß oder das rückwärtige Entlüften von Rohmateriallieferungen in den anliefernden Tanklastzug sind relativ einfach und kosteneffektiv zu installierende Maßnahmen, die bei der Eindämmung von Geruchsemissionen hilfreich sind.
- Gewährleistung, dass laute Geräte, deren Lärmpegel am Ursprungsort nicht hinreichend gemindert werden kann, nur so lange wie unbedingt erforderlich betrieben werden, und dass lärmindernde Maßnahmen zum Schutz der Umwelt, wie das Schließen von Türen und Fenstern, durchgängig angewendet werden. Außerdem sind die Bestimmungen der Europäischen Gemeinschaft über Gesundheit und Sicherheit am Arbeitsplatz [243, EC, 2003] ebenfalls von Bedeutung.

### Anwendbarkeit

In allen Anlagen zur Nahrungsmittelproduktion anwendbar.

### Anlass für die Umsetzung

Die routinemäßige Verfolgung der Umweltauswirkungen kann dazu beitragen, dass verstärkt ein geringerer Verbrauch und niedrigere Emissionswerte angestrebt werden, was wiederum zur Kostenersparnis und einem größeren Vertrauen der Aufsichtsbehörden beiträgt.

### Beispielanlagen

Viele Nahrungsmittelproduktions-Anlagen.

### Referenzliteratur

[205, DoE SO and WO, 1997]

## **4.1.3 Planung von Maschinen, Ausrüstung und Einrichtung**

### **4.1.3.1 Planung der Ausrüstung zur Reduzierung von Verbrauchs- und Emissionswerten**

#### Beschreibung

Durch die sorgfältige Planung von Pump- und Fördergeräten lassen sich Feststoff-, Flüssigkeits- und Gasemissionen verhindern. Der Energieverbrauch lässt sich z. B. durch energieoptimierte Planung einschließlich der Wiederverwendung von Wärme und der Verwendung von Isolierungen minimieren. Tanks, Pumpen, Kompressorabdichtungen und -ventile sowie Anlagenentleerungen können erhebliche Emissionsquellen darstellen. Beispiele für effektive Planungs- und Konstruktionsmaßnahmen sind u. a.: Identifizierung und Kennzeichnung aller Ventil- und Geräteeinstellungen zur Verringerung des Risikos von Falscheinstellungen durch das Personal; Optimierung von Rohrleitungssystemen und Gerätekapazitäten zur Reduzierung von Produktverlusten; Optimierung von Extraktionskapazitäten und Vorrichtungen zur Verminderung von Luftemissionen, z. B. bei Be- und Entladevorgängen; Installation von Rohren zur selbständigen Entleerung.

Die Planung von leicht zu reinigenden Gerätschaften erleichtert auch die Rückgewinnung von Produkten, und zwar sowohl für deren bestimmungsgemäßen Gebrauch im Prozess als auch für andere Verwertungen, z. B. als Tierfutter. Durch Trockenreinigungen lassen sich außerdem Wasserverbrauch und Abwassermenge senken.

Werden Gerätschaften so geplant, dass Umladeoperationen minimiert werden, so verringert sich auch das Risiko von Verschüttungen und Emissionen in die Luft.

Erreichbare Umweltvorteile

Geringerer Verbrauch von Energie, Wasser und Stoffen sowie geringere Emissionen in Luft, Wasser und Boden.

Betriebsdaten

Beispiele für die Minimierung von Luftemissionen auf dem Wege der Geräteplanung sind unter anderem die Ausstattung von Becken mit schwimmenden Abdeckungen und von Pumpen mit doppelten mechanischen Abdichtungen. Kühlanlagen und andere Geräte wie Kessel und Kühltürme lassen sich in der für den maximal zu erwartenden Bedarf ausreichenden Größe beschaffen und so regeln, dass sie jederzeit genau die benötigte Leistung liefern. In manchen Fällen lässt sich die Erzeugung von Luftemissionen durch genaue Messungen und oft komplexe Regelmechanismen minimieren. Installierte Steuersysteme müssen außerdem regelmäßig und effektiv gewartet werden, damit ein ordnungsgemäßer und unterbrechungsfreier Betrieb gewährleistet ist.

Fördergeräte lassen sich vollständig nach außen abschließen und abdichten, oder, wenn ein solcher Abschluss nicht machbar ist, mit lokalen Abzugshauben zum Auffangen von Emissionen ausstatten. Emissionen lassen sich auch durch die Minimierung der Förderstreckenlänge und der Zahl der Umschlagpunkte reduzieren. Fördergeräte können selbstentleerend und ohne Toträume gestaltet sowie mit Abläufen versehen werden, damit das Reinigen erleichtert wird.

Lärm lässt sich reduzieren, indem Motoren, wo immer möglich, mechanisch von den angeschlossenen Rohren und Leitungen isoliert werden. Bei Flüssigkeitssystemen können außerdem Geräusch- und Pulsationsdämpfer eingesetzt werden, um die Übertragung des mit der Flüssigkeit getragenen Lärms in das Leitungssystem zu verringern. Bei Feststoffsystemen, wie Rutschen und Schüttgutbehältern, lässt sich der durch das Auftreffen der Feststoffe auf der Rutsche bzw. dem Schüttgutbehälter entstehende Lärm reduzieren, indem abrupte Richtungsänderungen vermieden und die Aufprallkräfte möglichst gering gehalten werden, z. B. durch Wahrung eines Rutschkontakts der Produkte mit der Rutsche und durch Minimierung der Fallhöhe. Wenn Aufprallgeräusche unvermeidlich sind, kann lärmdämpfendes Auskleidematerial verwendet werden.

Wartungsarbeiten können schon bei der Planung berücksichtigt werden, z. B. indem Wasserleitungen, Ventile und Werkzeuge leicht zugänglich gemacht werden.

Es kann auch eine Integration von Prozesstechniken möglich sein, um die mögliche Produktausbeute zu maximieren und die Emissionen in die Umwelt insgesamt zu minimieren.

Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

Anlass für die Umsetzung

Reduzierung der Verbrauchs- und Emissionswerte und der damit verbundenen Kosten.

Referenzliteratur

[13, Environment Agency of England and Wales, 2000, 31, VITO, et al., 2001, 34, Willey A R and Williams D A, 2001, 65, Germany, 2002, 182, Germany, 2003, 200, CIAA, 2003, 234, UK, 2003, 242, Lewis D. N., 2003]

**4.1.3.2 Auswahl effizienter und geräuscharmer Ventilatoren**Beschreibung

Die Hauptursache für Ventilatorlärm sind Turbulenzen und die örtlich begrenzte Verzögerung von Flussraten durch Wirbelablösung. Unter Wirbelablösung versteht man die regelmäßige Entstehung von Wirbeln an einem sich in einem Flüssigkeitsstrom befindenden stumpfen Objekt, wodurch dieses Objekt einer veränderlichen Krafteinwirkung ausgesetzt ist.

Die Ventilatoren mit der geringsten Schaufelumfangsgeschwindigkeit, also mit großem Durchmesser und niedriger Umdrehungszahl, sind normalerweise die effizientesten und geräuschärmsten. Bei gegebener Aufgabe ist ein rückwärts gekrümmter oder rückwärts geneigter, mit Spitzeneffizienz arbeitender Ventilator leiser als ein Radialventilator.

Zusätzliche Lärmreduktionsmaßnahmen sind unter anderem die Verwendung elastischer Verbindungen zwischen Ventilatoren und Leitungen zur Minimierung der Vibrationsübertragung und die Montage von

Ventilatoren auf Schwingungsdämpfern, um die Übertragung der Vibrationen auf tragende Strukturen zu verhindern.

### Erreichbare Umweltvorteile

Verringerte Lärmemissionen.

### Betriebsdaten

In einem Beispiel-Sprühtrockner wurde ein Ventilator mit einer festen Umdrehungszahl von  $2.500 \text{ min}^{-1}$  und einer Leistung von  $45.000 \text{ m}^3/\text{h}$  Luftvolumen durch zwei kleinere, mit  $1.500 \text{ min}^{-1}$  laufende Ventilatoren und derselben Leistung ersetzt. Die Steuerung der neuen Ventilatoren erfolgte durch Verringerung der Umdrehungszahl anstatt der Verwendung eines Dämpfers. Die Nettolärmreduktion betrug ungefähr 8 dB(A). Tabelle 4.2 zeigt die durch Verringerung der Umdrehungszahl zu erwartende Lärminderung. Jede Reduktion um 3 dB(A) entspricht einer Halbierung des Lärmpegels.

| Senkung der Umdrehungszahl | Lärminderung |
|----------------------------|--------------|
| 10 %                       | 2 dB(A)      |
| 20 %                       | 5 dB(A)      |
| 30 %                       | 8 dB(A)      |
| 40 %                       | 11 dB(A)     |
| 50 %                       | 15 dB(A)     |

**Tabelle 4.2: Leitwerte zur Lärminderung durch Verringerung der Umdrehungszahl von Ventilatoren**

### Anwendbarkeit

Anwendbar, wo Ventilatoren zum Einsatz kommen, z. B. bei Klimaanlage, Belüftung und Kühlung.

### Wirtschaftlichkeit

Am billigsten, aber meist auch am lautesten, sind normalerweise die Ventilatoren mit dem geringsten Durchmesser. Die Kosten eines Ventilators stellen normalerweise jedoch einen relativ kleinen Teil der Kosten eines Gesamtprojekts dar, sodass sie nicht der bestimmende Faktor sind.

### Anlass für die Umsetzung

Reduzierung des Auftretens von Beschwerden über Lärmemissionen von außerhalb der Anlage.

### Referenzliteratur

[200, CIAA, 2003, 242, Lewis D. N., 2003]

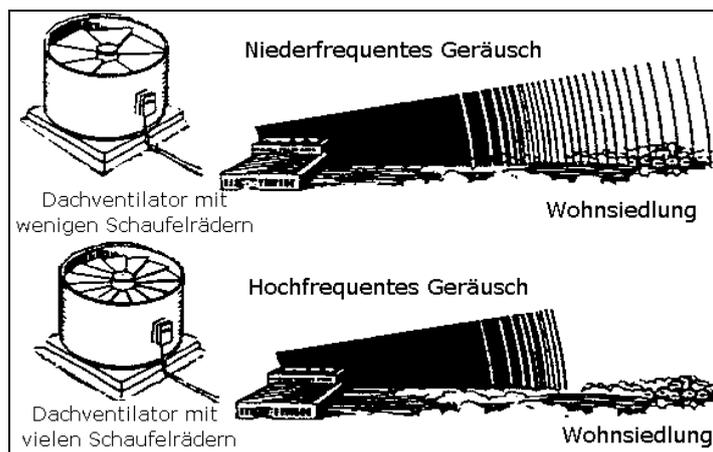
### **4.1.3.3 Auswahl von Ventilatoren mit geringer<sup>2</sup> Schaufelzahl**

#### Beschreibung

Lüftergeräusche werden über weite Entfernungen übertragen. Die von Lüftern mit vielen Schaufelblättern erzeugten höheren Frequenzen klingen über kürzere Distanzen schneller ab als die niedrigeren Frequenzen von Lüftern mit weniger Schaufeln. Abbildung 4.1 zeigt den Effekt, der sich aus der Umrüstung eines auf dem Dach montierten Lüfters auf höherfrequente Geräusche ergibt.

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<sup>2</sup> Anm. d. Übers.: Eigentlich müsste es dem Inhalt des folgenden Textes nach hier heißen: mit **vielen** Schaufeln.



**Abbildung 4.1: Einfluss der Anzahl der Schaufelblätter auf die Geräuschübertragungsdistanz**

#### Erreichbare Umweltvorteile

Verringerte Geräuschemissionen.

#### Anwendbarkeit

Anwendbar, wo Lüfter zum Einsatz kommen, z. B. bei Klimaanlage, Belüftung und Kühlung.

#### Anlass für die Umsetzung

Weniger Beschwerden über Geräuschemissionen von außerhalb der Anlage.

#### Referenzliteratur

[65, Germany, 2002]

### **4.1.3.4 Planung von Rohrleitungen zur Minimierung von Geräuschemissionen**

#### Beschreibung

Rohrleitungen können in Wänden oder in speziellen Kanälen verlegt werden, um die Geräuschmissionen zu mindern. Optimale Ergebnisse lassen sich entweder durch Auskleiden oder Auffüllen von Hohlräumen mit schallschluckendem Material erzielen. Die Schallisolierung lässt sich verbessern durch:

- Auswahl von Rohrleitungsmaterial mit schallisolierenden Eigenschaften, z. B. Gusseisen statt Kunststoff;
- Erhöhung der Rohrleitungswandstärke;
- Ummantelung der Rohrleitungen mit Vorsatzschalen.

Material und Geometrie der Rohrwand bestimmen die Ausbreitung des Luftschalls. Eine Dämpfung der Luftschall verursachenden Rohrwandschwingungen führt dazu, dass die Energie des Schalls bei seiner Ausbreitung in der Flüssigkeit reduziert wird. Bei niedrigen Frequenzen ist dieser Dämpfungseffekt nicht von Bedeutung, nimmt aber mit steigender Frequenz zu. Der Dämpfungseffekt nimmt mit zunehmendem Rohrdurchmesser ab. Rauigkeiten in der Rohroberfläche verstärken den Dämpfungseffekt. Wenn Rohrleitungen über eine schallabsorbierende Innenauskleidung verfügen, wird bei höheren Strömungsgeschwindigkeiten die Dämpfung der Schallausbreitung in Strömungsrichtung erheblich gemindert und die Dämpfung der Schallausbreitung entgegen der Strömungsrichtung erhöht.

Bei der Dimensionierung von Rohrleitungen ist darauf zu achten, dass die Hauptanregungsfrequenz des in das Rohr eingespeisten Schallleistungspegels einen ausreichenden Abstand zu den Eigenfrequenzen und Durchlassfrequenzen der Rohre hat. Alle Eigenfrequenzen werden von der Art der Rohrbefestigung, von der Trassenführung, z. B. der Anzahl und Position von Rohrkrümmern, sowie von Einbauten beeinflusst.

#### Erreichbare Umweltvorteile

Verringerte Geräuschemissionen.

#### Betriebsdaten

Rohrleitungen werden für den Transport von Gasen, Dämpfen, Flüssigkeiten und Feststoffen in Trägerflüssigkeit verwendet. Die Geräuschemissionen von Rohrleitungen umfassen den von den Flüssigkeiten und

Feststoffen übertragenen Geräusche sowie den Luftschall. Laminare Strömungen erzeugen praktisch keinen Lärm, allerdings führen Turbulenzen zu erhöhten Lärmpegeln in den Rohren.

Kavitation führt zu intensivem Störschall. Kavitation tritt auf, wenn der statische Druck örtlich gleich oder kleiner als der Dampfdruck wird, z. B. bei Strömungsumlenkungen.

Wenn Feststoffe mit Hilfe von Trägerflüssigkeiten transportiert werden, treten zusätzliche Geräuschquellen durch die Berührung der Feststoffteile gegenseitig und mit der Rohrleitungswand auf, insbesondere, wenn harte Partikel mit einer gasförmigen Flüssigkeit transportiert werden. Die Höhe des Schalldruckpegels ist abhängig von der Strömungsgeschwindigkeit, dem Rohrmaterial und der Art des Feststoffs. Im Abstand von 1 Meter zu geraden Rohrleitungsstücken können Schalldruckpegel zwischen 85 und 100 dB(A) auftreten. Im Bereich von Rohrkrümmern ist eine Zunahme um weitere 10 bis 15 dB(A) zu erwarten.

### Anwendbarkeit

Anwendbar, wo Rohrleitungen für den Transport von Gasen, Dämpfen, Flüssigkeiten und Feststoffen in Trägerflüssigkeit verwendet werden.

### Anlass für die Umsetzung

Vorbeugung gegen durch Lärm am Arbeitsplatz bedingte Gehörschäden und weniger Beschwerden über Lärmemissionen von außerhalb der Anlage.

### Referenzliteratur

[65, Germany, 2002]

## 4.1.3.5 Schallsolierung von Geräten

### Beschreibung

Quellen von Lärmverschmutzung können mit schallsolierenden Verschaltungen verkleidet werden. Eine isolierende Verschaltung besteht üblicherweise aus einer Metallhülle, die mit absorbierendem Material ausgekleidet ist und die Schallquelle vollständig oder teilweise umschließt. Die damit zu erreichende Reduktion des Lärmpegels hängt von der Isolierung des Luftschalls durch die Wände und von der Absorptionskapazität der inneren Auskleidung ab. Größe, Form und Material der Abschirmung lassen sich durch Berechnungen des Schallpegels ermitteln, damit die jeweiligen Lärmemissionswerte auch erreicht werden. Das Verbinden von Ventilatoren mit Leitungen und Gehäusen mit elastischem Material und das Platzieren von lauten Geräten auf schallschluckenden Sockeln können ebenfalls Lärmemissionswerte senken.

### Erreichbare Umweltvorteile

Verringerte Lärmemissionen.

### Betriebsdaten

Beispiele für die Benutzung schallsolierenden Materials in der Nahrungsmittelproduktion:

- Verschaltung von Glasflaschentransportbändern<sup>3</sup> und Verschlusskappenbehältern in Glasflaschenbefüllungslinien<sup>4</sup>
- Innenauskleidung von Schüttgutbehältern mit aufpralldämpfendem Material und Verkleidung der Außenseiten solcher Behälter und Schutzpaneele
- Auskleidung von Abdeckplatten und Verschaltung von Verpackungslinien bei Packmaschinen
- Montage von schalldämpfenden Hauben über Kuttern im Fleischsektor
- Isolierung von Homogenisatoren (z. B. in schallsolierten Räumen, die nicht oft aufgesucht werden müssen) in der Milchwirtschaft
- Isolierung von Sprühtrocknern (z. B. in schallsolierten Räumen, die nicht oft aufgesucht werden müssen)
- Bei Mahleinrichtungen Verschaltung von Hammermühlen, Walzenmühlen und Mischern

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<sup>3</sup> Anm. d. UBA-Bearb.: Ist technisch kaum durchzuführen und daher als sinnwidrig zu betrachten.

<sup>4</sup> Anm. d. UBA-Bearb.: Dies ist aber zumindest bei Brauereien und m. E. auch bei anderen Getränkeherstellern nicht machbar, da man zum einen nicht mehr in den laufenden Betrieb mal schnell eingreifen könnte und zum anderen wäre dies aus mikrobiologischer Sicht sehr problematisch.

- Verschalung der Kühlgeräte in Tiefkühl- und Kühlräumen, wobei die nötigen Belüftung von Motoren und Ventilatoren sichergestellt sein muss
- Verschalung von Dampfkompressoren.

Bei manchen Anwendungen kann es erforderlich sein, den Luftaustausch in Schallkanälen zu ermöglichen. Eine Lärminderung kann durch den Einbau von Rohrkrümmern in die Luftwege erreicht werden. So können beispielsweise Lüfter in schallisierende Kanäle eingeschlossen werden, die so konstruiert sind, dass sie die Anreicherung reflektierten Schalls innerhalb des Kanals reduzieren. Es muss dann für ausreichende Belüftung zur Kühlung des Lüfters gesorgt sein.

Bei Luftleitungen lässt sich anstelle der Ausstattung mit Schalldämpfern oft eine Minderung des Luftschalls aus einer Leitung oder Öffnung um 10 bis 20 dB(A) erzielen, indem der letzte Krümmer in der Leitung mit schallschluckendem Material ausgekleidet oder ein einfacher, mit Absorber ausgekleideter rechtwinkliger Aufsatz an der Öffnung angebracht wird. Angabegemäß sollten beide Seiten des Rohrkrümmers auf einer Länge ausgekleidet werden, die dem doppelten Leitungsdurchmesser entspricht.

#### Anwendbarkeit

Bei einer Reihe von in der Nahrungsmittelproduktion eingesetzten Geräten, z. B. Gebläsen, Kompressoren, Pumpen und Lüftern.

#### Anlass für die Umsetzung

Vorbeugung gegen durch Lärm am Arbeitsplatz bedingte Gehörschäden und weniger Beschwerden über Lärmemissionen von außerhalb der Anlage.

#### Beispielanlagen

Die Isolierung lärmzeugender Anlagen ist in der Nahrungsmittelproduktion weit verbreitet, z. B. in Glasflaschenbefüllungsanlagen, bei Schüttgutbehältern, bei denen es zu lautem Aufprall von Produkten kommt, bei der Verpackung, z. B. beim Einwickeln, Schneiden und bei der Beutelabfüllung, bei im Fleischsektor verwendeten Kuttern, beim Mahlen von Getreide wie z. B. bei der Herstellung von Mehl und Tierfutter und beim Einfrieren und Kühlen.

#### Referenzliteratur

[200, CIAA, 2003, 242, Lewis D. N., 2003]

### **4.1.3.6 Positionierung von Geräten so, dass der Schall nicht auf Anrainer gerichtet ist**

#### Beschreibung

Manche Geräte erzeugen in unterschiedlichen Richtungen unterschiedliche Lärmpegel. So sind z. B. bei allen Geräten die Lärmpegel an der Seite am höchsten, an der sich Zu- oder Abluftöffnungen für Gebläse befinden. Wird das Gerät so aufgestellt, dass die lauteste Seite von empfindlichen Standorten abgewandt ist, so gehen dort möglicherweise die Immissionspegel zurück. Ein Erfolg ist nicht immer garantiert, da die Schallrichtung sich mit der Wetterlage ändert.

#### Erreichbare Umweltvorteile

Geringere Lärmpegel bei „Empfängern“ auf der von der lauten Geräteseite abgewandten Seite.

#### Medienübergreifende Auswirkungen

Wird die Lärmemission in keiner Weise verhindert oder gemindert, so bleibt das Risiko von Gehörschäden durch Lärm am Arbeitsplatz oder Beschwerden bestehen.

#### Anwendbarkeit

Anwendbar bei Kühltürmen, Kondensatoren, Kompressoren, Pumpen und Gebläsen.

#### Anlass für die Umsetzung

Geringere Lärmpegel bei empfindlichen „Empfängern“.

#### Referenzliteratur

[65, Germany, 2002, 200, CIAA, 2003, 242, Lewis D. N., 2003]

### 4.1.4 Aspekte bei der Anlagenplanung

#### Beschreibung

Es gibt eine Reihe von Faktoren, die bei der Erstplanung eines Gebäudes zu berücksichtigen sind, wenn es um die Verminderung auftretender Luftemissionen und von Lärm geht.

#### Erreichbare Umweltvorteile

Geringere Luftemissionen und in vielen Fällen auch weniger Abfall.

#### Betriebsdaten

Die Lagerung und Handhabung von Rohstoffen ist besonders hinsichtlich übelriechender Emissionen wichtig. So kann z. B. der Lagerbereich so geplant werden, dass ein FIFO-System eingesetzt werden kann. Dies kann beispielsweise durch Lagerung in selbstentleerenden Schüttgutbehältern erreicht werden, durch die sichergestellt wird, dass die zuerst eingetroffenen Stoffe zuerst verwendet werden, da der Behälter von oben beladen und von unten entleert wird. Dadurch können Stoffe in frischem Zustand verarbeitet werden, der Einsatz von Rohstoffen wird optimiert und die Abfallerzeugung minimiert.

In Lagerhäusern lässt sich das Risiko von Produktverlusten und Verschüttungen verringern, wenn sie auf einfache und sichere Bewirtschaftung ausgelegt werden; z. B. können Lagerregale so geplant werden, dass sie mit einem Gabelstapler effizient bedient werden können.

Be- und Entladebereiche lassen sich so planen, dass häufige und effektive Reinigungen möglich sind, indem Oberflächen glatt gehalten und Ecken und andere schwer zugängliche und schwer zu säubernde Bereiche minimiert werden.

Bei extrem umweltverschmutzenden Stoffen kann das Gebäude so geplant werden, dass es auch während anormaler Betriebsbedingungen, wenn normale Steuersysteme nicht ausreichen würden, nicht zu Luftemissionen, z. B. durch gestörte Geräte, Lecks oder während Reparaturen, kommt. Die Zahl der Eingänge in das Gebäude kann minimiert und diese durch Doppeltüren mit dazwischen gelegener Luftschleuse geschützt werden.

Wenn Räume mit glatten Wänden und abgerundeten, leicht zu reinigen Ecken konzipiert werden, wird u. U. auch die Rückgewinnung von Stoffen für den Gebrauch bzw. die Entsorgung optimiert. Auch der Wasser- und Reinigungsmittelverbrauch und damit die anfallenden Abwassermengen und -belastungen lassen sich so reduzieren.

#### Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

#### Anlass für die Umsetzung

Geringere Luftemissionen und in vielen Fällen auch weniger Abfall und Abwasser.

#### Referenzliteratur

[34, Willey A R and Williams D A, 2001]

#### 4.1.4.1 Schallsolierung von Gebäuden

##### Beschreibung

Die Schallabgabe von Maschinen und die akustischen Eigenschaften der Räume bestimmen die Schalldruckpegel innerhalb eines Gebäudes. Diese inneren Schalldruckpegel und die durch die äußere Hülle, also durch Wände, Dächer, Fenster, Türen und Öffnungen gegebene Schallsolierung ergeben die Luftschalleistung, also den Emissionspegel. Das kann insbesondere zum Problem werden, wenn sich Geräte in Stahlgerüstbauten mit relativ leichtgewichtigen Profilverkleidungen befinden. Die Schalleistung einer Quelle steht in Beziehung zu ihrer Oberfläche. Große Gebäudefassaden können daher erhebliche Schalleistungen abgeben.

Gebäude lassen sich gegen Luftschall isolieren. Hochfrequenter Lärm lässt sich viel leichter abschirmen als niederfrequenter Lärm. Es kann entweder eine ein- oder doppelwandige Isolierung erfolgen. Die Schallsolierung von Komponenten, die eine mehr oder weniger homogene Struktur aufweisen, hängt stark von deren Gewicht pro Einheitsfläche ab. Auch die Natur des Materials ist von Bedeutung.

Doppelwandige Gebäude bestehen aus zwei dichten Wänden, die durch einen Luftspalt oder eine elastische Isolierschicht voneinander getrennt sind. Unter bestimmten Bedingungen ist die mit solchen Elementen erzielte Schallisolierung besser als bei einwandigen Elementen desselben Gewichts. Die wichtigste Voraussetzung für eine bessere Schallisolierung ist die ausreichende Breite des Luftspalts zwischen den Wänden bzw. die ausreichende Elastizität und eine offene Textur der Isolierschicht. Der Isoliereffekt des Hohlraums wird durch Befüllung mit schallschluckenden Materialien wie z. B. Mineralfaserplatten erreicht. Steife Verbindungen zwischen den zwei Wänden beeinträchtigen die Schallisolierung.

Die Schallisolierung einer Wand ist nur so gut wie ihre schwächste Stelle. Die Schallisolierung von Fenstern, Türen, Dächern und Jalousien muss berücksichtigt werden, damit die Schallisolierung der gesamten Struktur berechnet werden kann. Wenn der Schalldämmungsindex von Fenstern und Türen dem der Wand entspricht oder ähnlich ist, wird die Gesamtleistung erhalten. Wenn eine schlecht schließende Tür und ein dünnes Fenster in eine Blockwand installiert werden, verringert sich die erzielbare Lärminderung erheblich.

Wenn bestimmte Planungsvorgaben einzuhalten sind, sollten Größe, Form und Materialien für die Abschirmung anhand von Schallplanungsberechnungen ermittelt werden.

#### Erreichbare Umweltvorteile

Verringerte Lärmemissionen.

#### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion, z. B. beim Einsatz von Ventilatoren in Klimatisierung, Belüftung und Kühlung.

#### Anlass für die Umsetzung

Weniger Beschwerden über Lärmemissionen von außerhalb der Anlage.

#### Referenzliteratur

[65, Germany, 2002, 200, CIAA, 2003, 242, Lewis D. N., 2003]

### **4.1.4.2 Abschirmung von Gebäuden gegen Lärmimmissionsbereiche**

#### Beschreibung

Durch die Abschirmung von Gebäuden gegenüber Lärmimmissionsbereichen wird der Schalldruckpegel in solchen Bereichen gesenkt. Der Abschirmeffekt kann durch benachbarte andere Gebäude erzielt oder durch den Bau von Barrieren wie Wänden und Dämmen erzeugt werden. Wenn sie mindestens die Sichtverbindung unterbrechen, sollen diese Maßnahmen in der Lage sein, einen Abschirmeffekt von mehr als 5 dB(A) zu bewirken. Je höher die Barriere und je dichter sie an der Lärmquelle oder dem Immissionsbereich gelegen ist, desto stärker ist der Abschirmeffekt.

#### Erreichbare Umweltvorteile

Verringerte Lärmemissionen.

#### Medienübergreifende Auswirkungen

Die Lärmemission wird in keiner Weise verhindert oder gemindert, sodass das Risiko von Gehörschäden durch Lärm am Arbeitsplatz oder Beschwerden fortbesteht.

#### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion, z. B. wo Ventilatoren, Kühltürme und Kondensatoren eingesetzt werden.

#### Anlass für die Umsetzung

Weniger Beschwerden über Lärmemissionen von außerhalb der Anlage.

#### Referenzliteratur

[65, Germany, 2002]

### 4.1.4.3 Installation eines Spiralturbulenzgenerators an einem Schornstein zur Minderung von Lärmemissionen

#### Beschreibung

An Türmen und Schornsteinen entlangströmende Luft erzeugt Lärm durch Stromwirbel und regt außerdem dem Schornstein zu Vibrationen an. Wird ein Spiralturbulenzgenerator installiert, stört dies die Stromwirbelbildung. Der Gradient des Turbulenzgenerators ist nicht konstant. Die Technik ist in Abbildung 4.2 dargestellt.

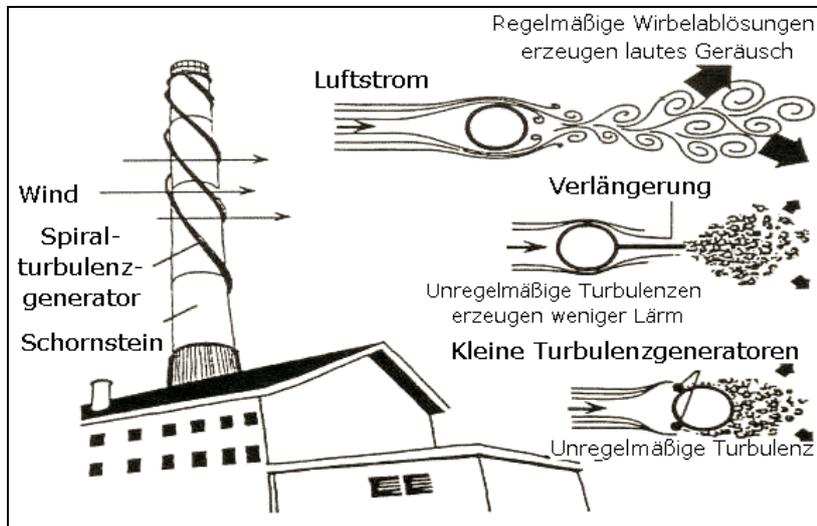


Abbildung 4.2: Minderung der Lärmemissionen an einem Industrieschornstein

#### Erreichbare Umweltvorteile

Verringerte Lärmemissionen.

#### Anwendbarkeit

Anwendbar, wo Ventilatoren zum Einsatz kommen, z. B. bei Klimaanlage, Belüftung und Kühlung.

#### Anlass für die Umsetzung

Weniger Beschwerden über Lärmemissionen von außerhalb der Anlage.

#### Referenzliteratur

[65, Germany, 2002]

### 4.1.5 Wartung

#### Beschreibung

Die effektive und geplante vorbeugende Wartung von Gefäßen und Geräten kann Häufigkeit und Umfang von Feststoff-, Flüssigkeits- und Gasemissionen sowie Wasser- und Energieverbrauch minimieren. So können beispielsweise Tanks, Pump- und Fördereinrichtungen, Kompressorabdichtungen und Ventile sowie Prozessabwässer erhebliche Emissionsquellen darstellen. Fehlerhafte Prozesssteuereinrichtungen können zu Lecks, zum Überlaufen und zu Tropfverlusten führen.

Der ordnungsgemäße Betrieb der Prozessinstallation kann regelmäßig überprüft werden. Sämtliche Abweichungen oder Änderungen lassen sich hinsichtlich ihrer Auswirkungen bewerten. Durch einfache Veränderungen in einem Prozess lassen sich Luftemissionen oft beträchtlich reduzieren.

#### Erreichbare Umweltvorteile

Geringerer Verbrauch von Energie, Wasser und Stoffen sowie geringere Emissionen in Luft, Wasser und Boden. Geringeres Abfallaufkommen, z. B. durch Rückgewinnung von Koprodukten/Nebenprodukten. Verringerte Lärmemissionen.

Betriebsdaten

Im Allgemeinen wird der Wartung von Versorgungssystemen eine viel geringere Priorität zugewiesen als einer Wartung, die sich direkt auf die Produktion oder die Sicherheit auswirkt. Das kann ein wesentlicher Faktor für übermäßigen Wasserverbrauch und die unnötige Erzeugung von Abwasser sein. Mit einem gut betriebenen Wartungssystem kann beispielsweise sichergestellt werden, dass Wasserlecks und Fehler, die zum Überlaufen oder zum Auslaufen in Abflüsse führen könnten, schnell behoben werden. Eine Optimierung der Kühlwassersysteme kann einen übermäßigen Vorausschlag des Kühlturms verhindern.

Beispiele für Wartungspraktiken sind u. a.:

## Allgemein

- Promptes Melden und Beheben von Leckagen.
- Sicherstellen, dass Greiferkanten ordnungsgemäß schließen, um das Herausrinnen von staubigen Feststoffen beim Umlagern zu vermeiden.

## Dampf

- Sicherstellen, dass die Inspektion von Kondensattöpfen eine dokumentierte Routinetätigkeit ist.
- Reparatur von Dampfleckagen.
- Sicherstellen, dass ein dokumentiertes System für die Meldung und Behebung von Dampfleckagen besteht.
- Sicherstellen, dass der Reparatur von Dampfleckagen eine hohe Priorität eingeräumt wird. Selbst bei nur wenigen leckenden Ventilstopfbuchsen können die Kosten schnell ansteigen.

## Druckluft

- Einrichten eines effektiven Systems zur Meldung von Leckagen.
- Überprüfungen außerhalb der Betriebsstunden, sodass Leckagen akustisch aufgespürt und gekennzeichnet werden können.
- Reparatur von Leckagen.

## Kältemittel

- Überprüfen des Kältemittelsichtglases auf Blasen im Sichtglas sind in der Regel ein Hinweis auf Lecks im System.
- Auffinden und Reparieren der Lecks vor dem Nachfüllen von Kältemittel in das System.
- Überprüfen, ob das Öl im Kompressorsichtglas die richtige Füllhöhe hat. Wenn der Ölstand zu niedrig – oder auch zu hoch – ist, steigt die Ausfallwahrscheinlichkeit des Kompressors.

## Kühlung

- Austritt von Materialien in ein Kühlwassersystem oder der Betrieb eines Kühlturmsystems zur direkten Kühlung von kontaminiertem Prozesswasser kann zu erheblich stärkeren Geruchsbelästigungen führen.

## Fisch

- Wartung der Enthäutungsmaschinen, z. B. durch das regelmäßige Schärfen von Klingen, um einen effizienten Enthäutungsprozess zu gewährleisten und um zu verhindern, dass Fischfleisch mit der Haut entfernt wird.

## Obst und Gemüse

- Verwendung scharfer Schneidköpfe beim Schneiden von Obst und Gemüse.

Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

Anlass für die Umsetzung

Reibungs- und problemlose Produktion, keine Unterbrechung durch Aus- und Unfälle. Gesetzliche Vorgaben. z. B. ist es illegal, bestimmte Kältemittel wissentlich an die Luft gelangen zu lassen.

### Beispielanlagen

In der gesamten Nahrungsmittelproduktion ist die vorbeugende Wartung weit verbreitet.

### Referenzliteratur

[1, CIAA, 2002, 13, Environment Agency of England and Wales, 2000, 31, VITO, et al., 2001, 69, Environment Agency of England and Wales, 2001, 134, AWARENET, 2002, 200, CIAA, 2003]

### **4.1.6 Methodik für die Vermeidung und Verminderung von Wasser- und Energieverbrauch und Abfallerzeugung**

Zur Vermeidung und Verminderung ist ein systematischer Ansatz erforderlich. Eine erfolgreiche Methodik umfasst üblicherweise die in den folgenden Abschnitten beschriebenen Schritte [1, CIAA, 2002]. Es werden folgende Schritte beschrieben:

- Schritt 1: Engagement des Managements sowie Organisation und Planung durch das Management
- Schritt 2: Analyse der Produktionsprozesse
- Schritt 3: Bewertung von Zielsetzungen
- Schritt 4: Aufzeigen von Möglichkeiten zur Vermeidung und Minimierung
- Schritt 5: Durchführung einer Evaluierungs- und Machbarkeitsstudie
- Schritt 6: Umsetzung des Vermeidungs- und Minimierungsprogramms
- Schritt 7: Laufende Überwachung durch Messungen und Sichtprüfungen.

Die Bedeutung der Vermeidung und Verminderung von Wasser- und Energieverbrauch und Abfallerzeugung wird im Folgenden beschrieben.

#### Vermeidung und Verminderung des Wasserverbrauchs

Wasservorräte sind nicht unbegrenzt, sodass eine Kontrolle des Wasserverbrauchs erforderlich ist. Dies stellt einen wichtigen Aspekt der Erhaltung natürlicher Ressourcen dar. In der Nahrungsmittelproduktion müssen die vorgeschriebenen Standards für Lebensmittelsicherheit und Hygiene erreicht werden. Das bedeutet, dass ein wesentlicher Teil des Wasserverbrauchs in diesem Sektor auf die Reinigung von Geräten und Anlagen entfällt. Durch einen systematischen Ansatz bei der Organisation der Wassernutzung lässt sich der Wasserverbrauch möglicherweise senken. Ein geringerer Wasserverbrauch bedeutet auch, dass weniger Abwasser behandelt werden muss. Das Vermeiden oder, falls nicht möglich, Vermindern der Wasserverschmutzung in Kombination mit anderen Techniken kann zu einem Rückgang der Wasserverschmutzung führen.

Die Wasserverschmutzung lässt sich durch die folgenden Maßnahmen einschränken:

- Verringerung des erzeugten Abwasservolumens
- Verringerung der Belastung des erzeugten Abwassers
- Vermeidung oder Verringerung der Konzentration bestimmter Schadstoffe, insbesondere der prioritären Schadstoffe.
- Kreislaufführung oder Wiederverwendung von Wasser
- Abwasserbehandlung

#### Vermeidung und Verminderung des Energieverbrauchs

In vielen Bereichen der Nahrungsmittelproduktion ist der Energieverbrauch ein wichtiger Kostenfaktor. Je nach Art der Produktionstätigkeit können die Energiekosten von weniger als 1 % bis zu über 10 % der Produktionskosten betragen. Ein systematischer Ansatz für die Verringerung des Energieverbrauchs ist sowohl unter Umweltgesichtspunkten (z. B. Treibhauseffekt) als auch unter Kosteneinsparungsaspekten wichtig.

In industriellen Anlagen wird zur Einschätzung des Energieverbrauchs oft das Konzept der Energieeffizienz verwendet. Energieeffizienz wird oft als die Menge Energie definiert, die je Produktionseinheit verbraucht wird. Eine Verbesserung der Energieeffizienz bedeutet also die Verringerung der je Produktionseinheit aufgewandten Energiemenge. Wenn der Produktausstoß gleich bleibt, bedeutet dies für die betreffende Anlage Energieeinsparungen. Bei der Verbesserung der Energieeffizienz lassen sich zwei Aspekte unterscheiden:

- Senkung des Energieverbrauchs durch effizientes Energiemanagement
- Senkung des Energieverbrauchs durch Prozessoptimierung und Innovationen.

Das Energiemanagement ist ein Ansatz zur Kontrolle und Verminderung des Energieverbrauchs und der Energiekosten. Es besteht im Wesentlichen darin, dass diejenigen, die für den Energieverbrauch verantwortlich sind, auch Rechenschaft darüber ablegen müssen. Wichtige Teile des Energiemanagements sind Überwachung und Zielvorgabe. In mehreren Fallstudien werden Energieeinsparungen von 5 % bis 15 % gemeldet.

Eine weitere Verbesserung der Energieeffizienz lässt sich durch Prozessoptimierung und Innovationen erzielen. Hierzu sind mitunter nur geringfügige Investitionen erforderlich. Dennoch sind für Innovationen, die wesentliche Auswirkungen sowohl auf das Verfahren als auch den Energieverbrauch haben, oft größere Investitionen notwendig. Wenn Investitionen in die Prozessoptimierung und Innovationen stattfinden, ohne dass ein effizientes Energiemanagementsystem besteht, so ist nicht klar festzustellen, ob die erwarteten Energieeinsparungen auch tatsächlich erzielt werden. Außerdem ist es möglich, dass die durch Prozessanpassungen erzielten Energieeinsparungen wieder aufgehoben werden, wenn keine gute handwerkliche Praxis betrieben wird.

Die Beziehung zwischen den Auswirkungen eines effizienten Energiemanagements und der Umsetzung von Energiesparmaßnahmen wie z. B. Prozessoptimierung und Innovation, wird in Abbildung 4.3 dargestellt.

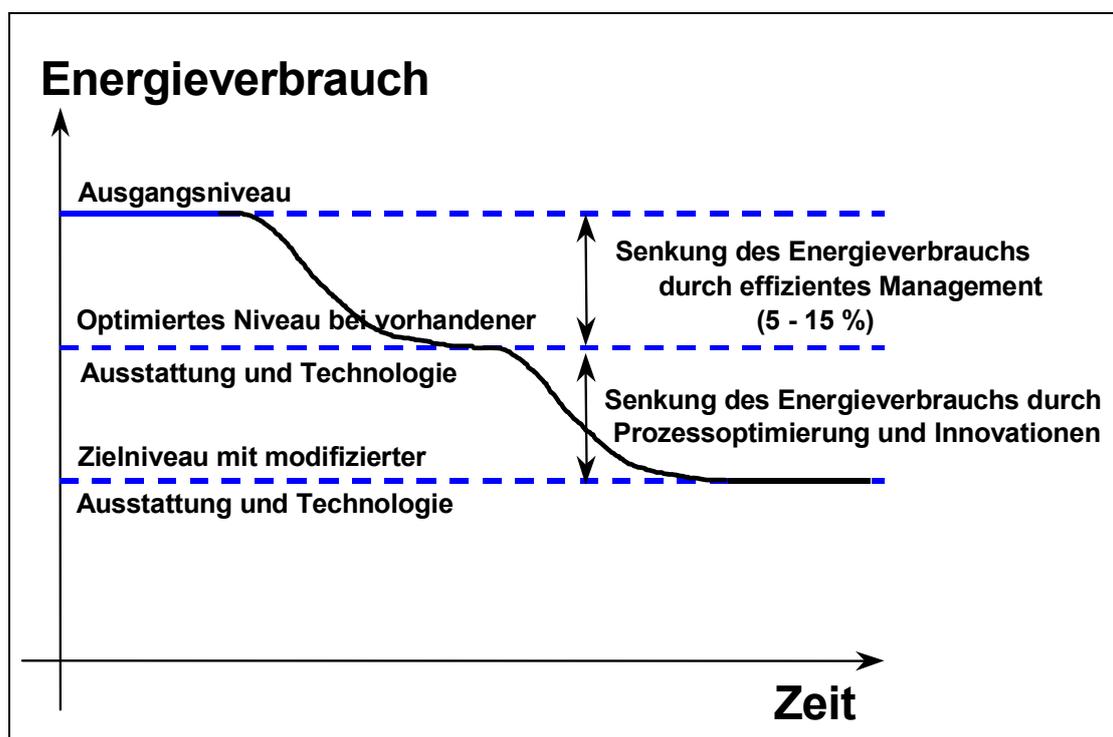


Abbildung 4.3: Verringerung des Energieverbrauchs  
[1, CIAA, 2002]

#### Vermeidung und Reduzierung von Abfallerzeugung

Die Vermeidung der Abfallerzeugung ist eines der Hauptziele der IVU-Richtlinie. Artikel 3 (c) besagt: „Die Mitgliedstaaten treffen die erforderlichen Vorkehrungen, damit die zuständigen Behörden sich vergewissern, dass die Anlage so betrieben wird, dass (c) die Entstehung von Abfällen entsprechend der Richtlinie 75/442/EWG des Rates vom 15. Juli 1975 über Abfälle vermieden wird; andernfalls werden sie verwertet oder, falls dies aus technischen oder wirtschaftlichen Gründen nicht möglich ist, beseitigt, wobei Auswirkungen auf die Umwelt zu vermeiden oder zu vermindern sind“. Anhang IV besagt: „Bei der Festlegung der besten verfügbaren Techniken, wie sie in Artikel 2 Nummer 11 definiert sind, ist unter Berücksichtigung der sich aus einer bestimmten Maßnahme ergebenden Kosten und ihres Nutzens sowie des Grundsatzes der Vorsorge und der Vorbeugung im Allgemeinen wie auch im Einzelfall Folgendes zu berücksichtigen: 1. Einsatz abfallarmer Technologie; und 2. Förderung der Rückgewinnung und Wiederverwertung der bei den einzelnen Verfahren erzeugten und verwendeten Stoffe und gegebenenfalls der Abfälle;“

In diesem Kapitel werden Techniken beschrieben, mit denen durch die Verwendung, Wiederverwendung, Rückgewinnung und Wiederverwertung von Nebenprodukten, Koprodukten, Rückständen und Materialien ver-

hindert werden kann, dass diese zu Abfall werden. So können beispielsweise Materialien, die ursprünglich in Lebensmitteln Verwendung finden sollten, die aber den Anforderungen des Kunden nicht genügen, obwohl sie sonst für den Verzehr geeignet sind, für die Verwendung in Tierfutter geeignet sein.

In einigen speziellen Fällen akzeptieren oder betrachten die Behörden das Aufbringen auf Land als Wiederverwertung oder Rückgewinnung. Andere Behörden verbieten es per Gesetz. Auf jeden Fall sollte die Ausbringung auf landwirtschaftlichen Nutzflächen ausschließlich in Übereinstimmung mit der EU-Umweltgesetzgebung einschließlich der Nitratrichtlinie [194, EC, 1991] erfolgen, mit der für sämtliche Stickstoffverbindungen hinsichtlich der Lagerung und der Ausbringung auf Nutzflächen bestimmte Maßnahmen vorgeschrieben werden; außerdem befasst sie sich mit bestimmten Landbewirtschaftungspraktiken und enthält Vorgaben dazu, wann die Ausbringung auf Nutzflächen verboten oder unangebracht ist. Vor der Ausbringung irgendwelcher Substanzen auf Nutzflächen sind mehrere wichtige Aspekte zu bewerten, z. B. landwirtschaftliche Interessen in Bezug auf die Wissenschaft von der Bodenbewirtschaftung und pflanzlichen Erzeugung, sowie Hygiene und Nachverfolgbarkeit. Berichten zufolge werden einige Transport-/Wasch-/Prozesswässer, überschüssige Biomasse aus biologischen Kläranlagen und andere feste Rückstände manchmal auf Nutzflächen ausgebracht. So eignen sich beispielsweise Kartoffelfruchtwasser, lösliche Bestandteile aus Weizen und die Schlämme aus der Abwasserbehandlung in der Stärkeindustrie sowie Zuckerrüben-transportwasser, möglicherweise erst nach dem Absetzen, für die Ausbringung auf Nutzflächen. Wenn beurteilt wird, ob die Ausbringung auf landwirtschaftlichen Nutzflächen möglich ist, sind beispielsweise folgende Aspekte zu berücksichtigen:

- Hat die ausgebrachte Substanz einen echten Nährwertnutzen für Pflanzen? Ein solcher Nutzen könnte z. B. in einer Verbesserung des pH-Gleichgewichts im Boden oder in der Zuführung von Düngerelementen wie Phosphor und Stickstoff bestehen.
- Gibt es geographische, pedologische (d. h. die Wissenschaft vom Boden, besonders von seiner Bildung, Natur und Klassifizierung betreffende), klimatische oder hydrogeologische Daten, die eine Auswirkung auf die Lebensmittel- oder Tierhaltungshygiene oder die Umwelt durch das Ausbringen der Substanz erwarten lassen? [81, France, 2001]
- Lassen sich in jedem Stadium des Betriebs Herkunft und Bestimmungsort der ausgebrachten Stoffe erkennen? Dies ist abhängig von der engen Zusammenarbeit zwischen dem Erzeuger der auszubringenden Substanz und der Person, die die Ausbringung steuert, z. B. dem Landwirt. [81, France, 2001]
- Es muss kontrolliert werden, ob die erwartete Auswirkung auch eintritt, z. B. durch Boden- und Grundwasseranalysen.[81, France, 2001]

Das **Ziel** eines Abfallvermeidungsprogramms ist es, die Umweltauswirkungen des Herstellungsbetriebs so weit wie praktisch machbar zu verringern, wobei Wirtschaftlichkeit und Umweltnutzen zu berücksichtigen und alle behördlichen Vorgaben zu erfüllen sind. Die Reduzierung von Materialeinsatz und Energieverbrauch trägt zur Einhaltung gesetzlicher Vorgaben bei und bedeutet für den Hersteller eine Senkung der durch Verluste von Produkt und Rohmaterial sowie durch die Entsorgung in- und außerhalb der Anlage anfallenden finanziellen Kosten. Natürliche Ressourcen werden geschont.

In der Nahrungsmittelproduktion sind Hygiene und Lebensmittelsicherheit unter Anwendung des HACCP-Konzepts von überragender Bedeutung. Maßnahmen zur Abfallvermeidung dürfen die bakteriologische Qualität des Produkts nicht gefährden. Wenn beispielsweise der geringste Verdacht hinsichtlich einer Nichterfüllung von Qualitätsstandards besteht, wird das Produkt erneut verarbeitet oder als Abfall deklariert. Außerdem ist eine gründliche Reinigung erforderlich, um das geforderte Niveau von Sauberkeit und Hygiene zu erzielen. Dadurch fällt allerdings Abwasser an. Üblicherweise lassen sich bei Reinigungsvorgängen Einsparungen vornehmen, die ohne Gefährdung der Hygiene des Endprodukts zu weniger Einleitung von kontaminiertem Wasser und Chemikalien in das Abwasser führen.

Diese Methodik liefert Anleitungen zum Management der Abfallvermeidung, wodurch sich auch die Verluste an Rohstoffen, Produkten und Hilfsstoffen und damit die Kosten reduzieren lassen. Wenn es angebracht ist, werden erfolgreiche Abfallvermeidungsmaßnahmen durch Fallstudien und dokumentierte Beispiele belegt. In Abschnitt 4.6 wird separat erörtert, wie die Entstehung von Abfall durch unbeabsichtigte Freisetzungen vermieden werden kann.

Informationen zu Methodiken für die Abfallminimierung finden sich in verschiedenen Leitfäden, darunter „Waste Minimisation – An Environmental Good Practice Guide For Industry“ der Umweltbehörde des Vereinigten Königreichs (2001), [64, Environment Agency of England and Wales, 2001] und in Publikationen

der Reihe zum Programm für beste Praktiken in der Umweltechnologie, wie z. B. „Waste Minimisation Pays: Five Business Reasons for Reducing Waste – GG 125“ [62, Envirowise (UK), et al., 1998] und „Cutting Costs by Reducing Waste: Running a Workshop to Stimulate Action – GG 106“ [63, Envirowise (UK) and William Battle Associates., 1998]. Durch die Anwendung effektiver Techniken in allen Hauptbereichen der Abfallerzeugung lässt sich mit hoher Wahrscheinlichkeit ein erheblicher Umweltnutzen erzielen. Eine Beispielmethode für die Abfallvermeidung und -reduzierung ist in Abbildung 4.4 dargestellt.

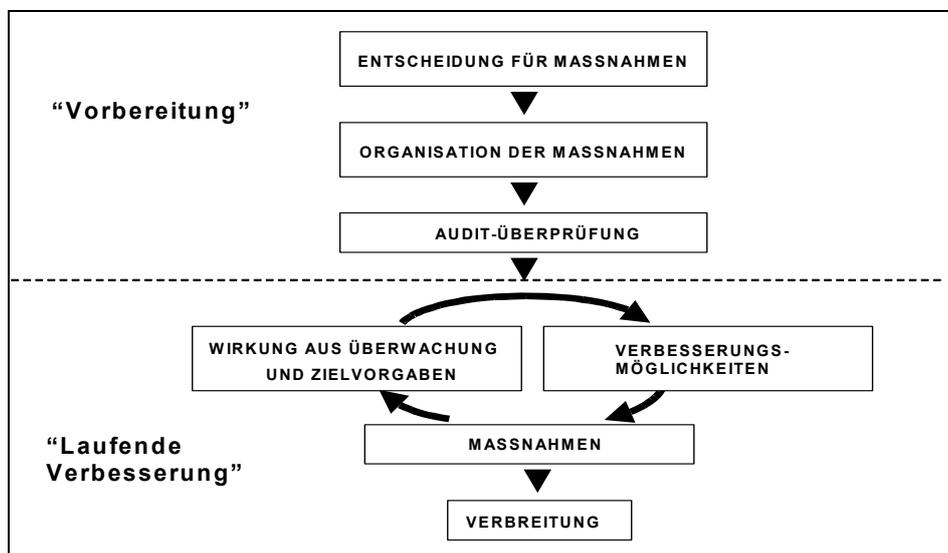


Abbildung 4.4: Beispiel für eine Methodik zur Abfallvermeidung und -reduzierung [11, Environment Agency of England and Wales, 2000]

#### 4.1.6.1 Schritt 1: Engagement des Managements sowie Organisation und Planung durch das Management

##### Engagement der Unternehmensleitung

Wenn Programme zur Vermeidung und Verminderung von Wasser- und Energieverbrauch sowie Abfallerzeugung erfolgreich sein sollen, müssen sie von der Führungsebene des Unternehmens unterstützt werden. Dadurch lässt sich sicherstellen, dass alle Einzelpersonen in der Organisation auf positive Weise zusammenarbeiten und der größtmögliche Nutzen aus der Initiative gezogen wird. Das Engagement der Führungsebene lässt sich am besten gewinnen, wenn der erzielbare finanzielle Nutzen aufgezeigt wird.

Es empfiehlt sich, zunächst ein oder zwei Bereiche zu identifizieren, in denen erhebliche Mengen an Materialien oder Produkten verlorengehen, in denen Abfall erzeugt wird oder in denen ein hoher Wasser- und Energieverbrauch gemessen wird, um dann die dadurch entstehenden Kosten für das Unternehmen aufzuzeigen. In dieser Kostenübersicht werden die Kosten für verschwendete Rohstoffe, Nachbearbeitungen, verlorene Produktionszeiten, Abfallbehandlung, verschwendete Arbeitskraft, Materialverlust an Luft und Abwasser sowie der übermäßige Verbrauch von Energie und Wasser aufgeführt.

Manchmal landen bis zu 25 % des Rohmaterials oder Produktäquivalents im Abfall oder Abwasser. Die obere Führungsebene ist sich der Größenordnung dieser Verluste oft nicht bewusst. Wenn sie darauf aufmerksam gemacht werden, setzen sich die oberen Führungskräfte möglicherweise uneingeschränkt für das Vermeidungs- und Verminderungsprogramm ein.

##### Organisation (Aufstellung eines Projektteams) (siehe auch Abschnitt 4.1.7.5 )

Es ist meistens nützlich, einen Teamleiter oder einen Unternehmensbeauftragten zu benennen, der die Programme koordiniert und unterstützt. Durch den Einsatz von Projektteams und Beauftragten lässt sich das Bewusstsein für die Problematik auf allen Ebenen steigern. Einzelne Mitarbeiter können so motiviert werden, aktiv zu werden und sich zu beteiligen. Der Teamleiter und das Projektteam können zuständig sein für die Durchführung von Bewertungen und für die Entwicklung und Einschätzung von Vorschlägen und Maßnahmen [63, Envirowise (UK) and William Battle Associates., 1998].

Planung

Die Ausarbeitung eines genauen Projektplans zusammen mit einem Zeitplan, der angibt, wann bestimmte Aktivitäten durchzuführen sind, kann für das Vermeidungs- und Minimierungsprogramm hilfreich sein. Erfolg ist zu erwarten, wenn Fortschritte überwacht und Einzelpersonen mit Handlungsverantwortung benannt werden und Rechenschaft ablegen müssen.

**4.1.6.2 Schritt 2: Analyse der Produktionsprozesse**

Eine wichtige Voraussetzung für die erfolgreiche Vermeidung und Minimierung von Energie- und Wasserverbrauch sowie der Abfallerzeugung ist ein guter Überblick über die Bereiche und Verfahrensschritte, die für Materialverluste, die Entstehung von Abfall und die Verbrauchsmengen relevant sind. Durch eine solche Übersicht lassen sich Maßnahmen leichter identifizieren. Dazu ist eine ausführliche Bestandsaufnahme für alle Produktionsprozesse erforderlich. Bei der Durchführung dieser Bestandsaufnahme lassen sich drei Messebenen unterscheiden.

Erhebung quantitativer Daten auf Standortebene

Auf dieser Ebene werden Daten bezüglich Mengen und Kosten für die gesamte Anlage, also den ganzen Standort, erhoben. Die meisten Daten sollten bereits in den Unterlagen des Unternehmens, wie z. B. Lagerbücher, Konten, Einkaufsquittungen, Abfallentsorgungsbelege und Produktionszahlen, vorhanden sein. Wenn Daten fehlen, sind Schätzungen oder direkte Messungen erforderlich.

Die Mengen von Rohmaterialien, Energie, Wasser und Abfall sind üblicherweise auf den Zeitraum eines Jahres bezogen. Die Einheiten müssen konsistent sein. Das ist wichtig, damit Mengen und Aktivitäten sowohl zum jeweils aktuellen Zeitpunkt als auch in der Zukunft sinnvoll miteinander verglichen werden können.

Die Daten können in systematischer Weise erhoben werden, sodass eine möglichst vollständige Erfassung der Ausgangslage gewährleistet ist. Normalerweise ist es sinnvoll, eine papierbasierte oder elektronische Datenbank aller erhobenen Daten zu pflegen.

Bestandsaufnahme für jeden Verfahrensschritt

Ziel dieses Schritts ist es, einen Überblick über alle Produktionsverfahren und die damit zusammenhängenden Umweltaspekte zu bekommen. In einem Flussdiagramm mit Eingangs- und Ausgangsgrößen und Umweltproblembereichen lassen sich die Produktionsprozesse anschaulich darstellen.

Abbildung 4.5 zeigt ein Beispiel für ein solches Eintrags-/Austragsarbeitsblatt. Eine Darstellung in anderen Formaten ist durchaus möglich [60, Environment Agency of England and Wales, 1998].

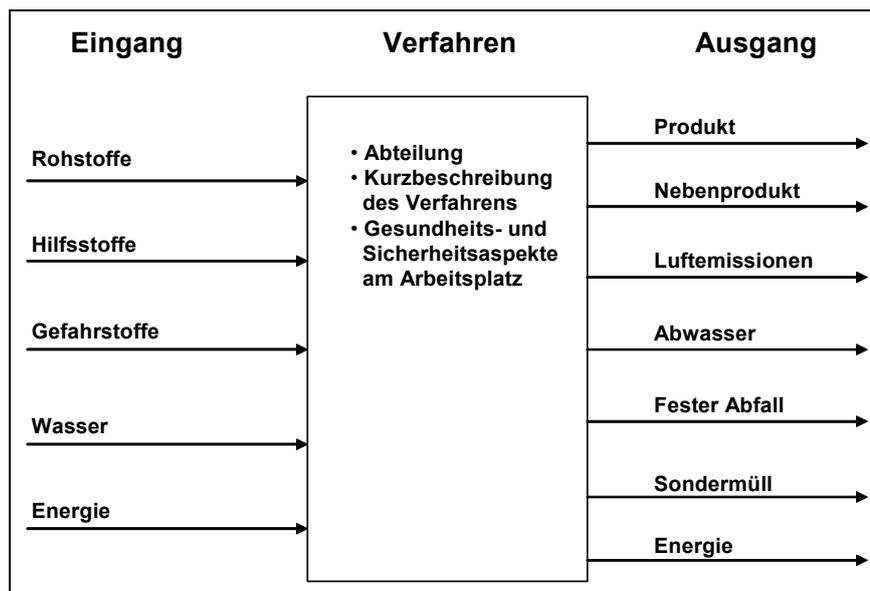


Abbildung 4.5: Beispielarbeitsblatt zur Identifizierung von Einträgen/Austrägen und Umweltproblemen [1, CIAA, 2002]

Es kann eine Stoffbilanz erstellt werden, die den Verbleib verbrauchter Rohstoffe und Dienste sowie die Verluste, Abfälle und Emissionen aufzeigt, die sich aus dem Verfahren ergeben. Anhand einer Stoffbilanz können zuvor unbekannte Verluste, Abfälle und Emissionen erkannt und quantifiziert werden; außerdem ergibt sie Hinweise auf deren Quellen und Ursachen. Stoffbilanzen sind einfacher, sinnvoller und genauer, wenn sie für einzelne Verfahrensschritte erstellt werden. Aus diesen Einzelbilanzen lässt sich dann die Gesamtstoffbilanz der Anlage erstellen.

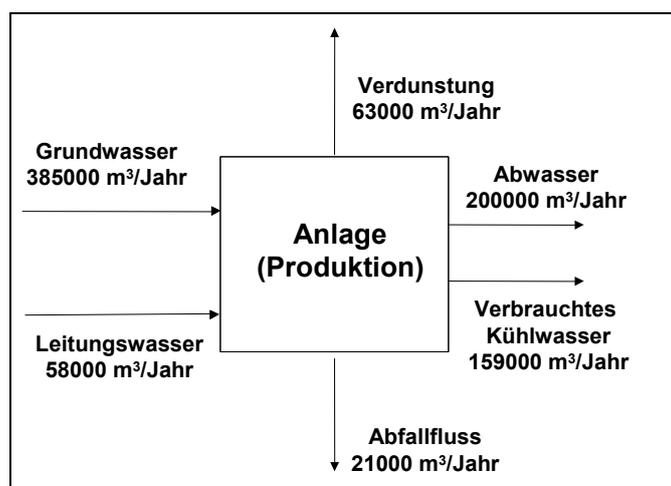
Die Stoffbilanz kann auch dazu verwendet werden, die Kosten für Einträge, Austräge und erkannte Verluste zu beziffern. Aus den Stoffbilanzdaten lassen sich dann Indikatoren für die Umweltleistung des Verfahrens entwickeln.

#### Bestandsaufnahme bei bestimmten Teilen

Je nachdem, was die Bestandsaufnahme auf Ebene der Verfahrensschritte ergeben hat, kann eine weitere Untersuchung von Teilen des Verfahrens/der Anlage zur Ermittlung von Möglichkeiten zur Vermeidung und Verminderung erforderlich sein. Dazu ist eine ausführlichere Bestandsaufnahme nötig, die sich auf die wichtigsten Aspekte oder Prozessbereiche konzentriert.

#### **4.1.6.2.1 Untersuchung von Produktionsprozessen mit dem Ziel der Vermeidung und Verminderung des Wasserverbrauchs**

Zunächst werden Wasserverbrauch und -ableitung der gesamten Anlage betrachtet. Dabei werden Verwendung und Aufbereitung des Wassers berücksichtigt, und zwar einschließlich des wiederverwerteten und wieder verwendeten Wassers, des in das Produkt (z. B. Getränke, Obst- und Gemüsekonserven) eingehenden Wassers, des verdampften Wassers und des für die Reinigung verwendeten Wassers. Üblicherweise wird zwischen dem Gesamtwasserverbrauch und dem Frischwasserverbrauch unterschieden. Der Gesamtwasserverbrauch und die Emissionswerte für eine Beispielanlage sind in Abbildung 4.6 dargestellt.



**Abbildung 4.6: Übersicht über die Wasserzufuhr und -abgabe einer Beispielanlage [1, CIAA, 2002]**

Anschließend muss ein Überwachungssystem eingerichtet werden. Dazu zählt auch die Identifizierung geeigneter Messpunkte für den Wasserverbrauch und die Implementierung eines Systems für die Datenerfassung, -verarbeitung und -ausgabe. Diese Daten lassen sich manchmal einfach aus bestehenden Durchflussmessungen, Wasser- und Abwasserrechnungen und aus den für Genehmigungen zusammengestellten Daten entnehmen. Außerdem kann es sinnvoll sein, eine Übersicht über die Kosten zu erstellen, die im Zusammenhang mit der Wasserzufuhr und -abgabe anfallen, da so deutlich wird, wo finanzielle Einsparungen möglich sind.

Anhand der in diesem Stadium erhobenen Daten lassen sich Kennzahlen (Benchmarks) identifizieren. Beispiele für solche Kennzahlen sind:

- der spezifische Wasserverbrauch ( $\text{m}^3$  Wasser/Tonne Rohstoff oder fertiges Produkt)
- die spezifische Abwassermenge ( $\text{m}^3$  Wasser/Tonne Rohstoff oder fertiges Produkt)

- das Verhältnis der Wasserkosten zwischen Wasserzufuhr und Wasserabgabe
- Wasserkosten pro Produktionseinheit
- Wasserverlust als prozentualer Anteil des Wasserverbrauchs.

Durch die Verwendung solcher Kennzahlen und, sofern möglich, den Vergleich mit externen Kennzahlen können erste Hinweise darauf gewonnen werden, ob Einsparungen möglich sind oder nicht.

Je nach Art der Anlage kann zwischen Abteilungen, Verfahrensarten und den Hauptebenen eines Verfahrens unterschieden werden. Neben den Produktionsprozessen müssen Wasseraufbereitung, Abwasserbehandlung und Reinigungstätigkeiten in die Bestandsaufnahme einbezogen werden, damit alle möglichen Einsparungen erkannt werden können.

Manchmal werden die Wasserströme für die wichtigsten Prozesse und Abteilungen bereits gemessen. Falls nicht, können entlang der wichtigsten Ströme Messgeräte installiert werden – manchmal auch nur vorübergehend. Eine andere Möglichkeit besteht darin, den Wasserverbrauch für die verschiedenen Produktionsprozesse zu schätzen, beispielsweise anhand des Produktionsvolumens; die Ergebnisse dieses Ansatzes sind jedoch weniger verlässlich.

Anhand der in diesem Stadium erhobenen Daten sollte es möglich sein, die Bereiche zu identifizieren, in denen weitere Untersuchungen im Hinblick auf Wassereinsparungen stattfinden sollen. Bei bestimmten Teilen des Prozesses kann jedoch für die Erkennung von Einsparmöglichkeiten eine genauere Analyse erforderlich sein. Dazu ist eine ausführlichere Bestandsaufnahme für diese Teile notwendig. Die ausgewählten Teile werden in logische Bausteine, d. h. relevante Prozessschritte, Arbeitsbereiche, Geräte und Anlagen unterteilt. Für jeden Baustein werden Wasserzufuhr und -abgabe ermittelt. Es kann außerdem wichtig sein, die Funktion des Wassers in dem betreffenden Teil anzugeben, z. B. Transportwasser, Waschwasser, Produktwasser oder Kühlwasser.

Häufig sind nicht alle Daten verfügbar, die auf dieser Detailebene benötigt werden. Fehlende Daten lassen sich durch zusätzliche Messungen, durch Berechnung aus anderen Daten oder auch durch Schätzungen ergänzen. Das hängt davon ab, wie wesentlich der betreffende Wasserstrom für das Gesamtschema ist. Damit die Bestandsaufnahme nicht zuviel Zeit erfordert und nicht zuviel Kosten verursacht, ist nur die unbedingt notwendige Detailebene zu wählen. Außerdem müssen die untersuchten Teile der Anlage genau definierbar sein und logisch erkennbare Bezeichnungen haben. Dabei kann die Verwendung von Plänen und Fließbildern für jede einzelne Ebene und jeden einzelnen Prozessteil helfen, wie auch eine einheitliche Datendarstellung. Hierfür können Fließbild-Softwareprogramme verwendet werden.

In jedem Prozessschritt können die Qualitätsanforderungen an das verwendete Wasser bewertet werden. Je nach Art des Prozesses sind die wichtigsten Kriterien im Allgemeinen das Vorhandensein organischen Materials aus Rohstoffen und Produkten, das Vorhandensein von Hilfsstoffen im Wasser, die Mikrobenzahl, der pH-Wert, der Chloridgehalt, die Härte sowie der Gehalt des Wassers an Eisen und Mangan. Es empfiehlt sich, die Prozessschritte nach der benötigten Wasserqualität zu gruppieren und die Zahl der definierten Wasserqualitäten auf maximal 5 bis 10 zu beschränken. Die definierten Qualitätsanforderungen sind so zu gestalten, dass die Wasserqualität die Qualität des Endprodukts nicht beeinträchtigt. Außerdem wird die jeweilige Qualität der Abflüsse der einzelnen Prozessschritte festgehalten. Diese Angaben sind nötig, um beurteilen zu können, ob sich Wasser – mit oder ohne zwischengeschaltete Behandlung – wieder verwenden lässt.

Schließlich lässt sich der reduzierte Wasserverbrauch manchmal anhand externer Kennzahlen schätzen. Voraussetzung dafür ist das Vorliegen von Daten für vergleichbare Aktivitäten. Ein anderer Ansatz zur Bestimmung des reduzierten Wasserverbrauchs geht von den technischen Geräte- oder Anlagendaten, beispielsweise von Lieferanten, und den verschiedenen Teilen der Prozesslinien aus. Die Aufsummierung der einzelnen Prozesswasserbedarfsmengen für die gesamte Anlage ergibt einen theoretischen Wasserverbrauchsentwurf und ermöglicht die Erarbeitung von Norm- oder Zielwerten.

#### **4.1.6.2.2 Untersuchung von Produktionsprozessen mit dem Ziel der Vermeidung und Verminderung des Energieverbrauchs**

Daten zum Energieverbrauch sind von grundlegender Bedeutung für die Ermittlung der effektivsten Energieeinsparungen und kosteneffektivsten Verbesserungen. Sie stellen außerdem die Grundlage eines Nachweises dafür dar, dass die Anlage effizient betrieben wird und Energiesparmaßnahmen in den am besten geeigneten Bereichen ergriffen werden.

Zuerst müssen die Daten nach Energiequellen aufgeschlüsselt werden. Neben dem eingekauften elektrischen Strom sollten hier auch Brennstoffe berücksichtigt werden, die vor Ort in Energie umgewandelt werden, sowie direkt von externen Quellen bezogene Wärme und erneuerbare Energiequellen. Es können die neuesten Werte für die Energielieferquellen eines erst kurz zurückliegenden Zwölfmonatszeitraums verwendet werden. Die Umrechnung in Primärenergie wird empfohlen. Wenn Energie aus einer KWK-Anlage verwendet wird (siehe Abschnitt 4.2.13.1.1) beruht die Berechnung der verwendeten Energie auf der Energiezufuhr zur Anlage, nicht auf den von der Anlage produzierten Energieeinheiten. Ein Beispielarbeitsblatt für die Aufschlüsselung des Energieverbrauchs findet sich in Tabelle 4.3.

| Energiequelle                              | Energieverbrauch |                          |                |
|--|------------------|--------------------------|----------------|
|  | Geliefert        | Primär<br>(kWh oder MWh) | Anteil in<br>% |
| Elektrischer Strom                         | MWh              |                          |                |
| Gas  | m <sup>3</sup>   |                          |                |
| Öl   | Tonnen           |                          |                |
| Bezogener Dampf                            | Tonnen           |                          |                |
| Energie aus Abfall/erneuerbaren<br>Quellen | kWh (MJ)         |                          |                |
| Sonstige, genaue Bezeichnung               |                  |                          |                |
| Abgegebener Dampf                          | Tonnen           |                          |                |
| Abgegebener elektrischer Strom             | MWh              |                          |                |

**Tabelle 4.3: Beispielarbeitsblatt für die Aufschlüsselung des Energieverbrauchs**  
[1, CIAA, 2002]

Als nächstes wird der Energieverbrauch der Geräte, aufgeschlüsselt nach Abteilung oder Produktionslinie, untersucht. Es ist ratsam, die Angaben zum Energieverbrauch durch Energiebilanzen oder Fließdiagramme zu ergänzen, um darzustellen, wie Energie während des gesamten Prozesses genutzt wird. Zur Darstellung von Situationen, in denen die Energieumwandlung stark in die Produktionsvorgänge integriert ist (siehe Beispiel in Abschnitt 4.2.13.1.1), kann ein Sankey-Diagramm verwendet werden.

Zuletzt wird der spezifische Energieverbrauch (SEC) untersucht. Darunter versteht man die Energiemenge, die pro Einheit des verarbeiteten Rohstoffs oder des erzeugten Produkts verbraucht wird.

#### 4.1.6.2.3 Untersuchung von Produktionsprozessen mit dem Ziel der Vermeidung und Verminderung der Abfallerzeugung

In jedem Stadium des Produktionsprozesses, vom Empfang bis zur Abgabe, kann es zu Verlusten kommen. So lassen sich beispielsweise Verluste durch schlechte Lagerung und Materialhandhabung erkennen, wenn ein genaues Bestandsverzeichnis der Ein- und Ausgänge in allen Stadien des Prozesses, von der Rohstoffannahme bis zur Produktabgabe und nachsorgenden Behandlungen, geführt wird. Bei diesen Verlusten kann es sich um angenommene oder echte Verluste handeln. In Tabelle 4.4 sind Beispiele für Ursachen von Materialverlusten sowie Methoden zur Pflege eines genauen Bestandsverzeichnisses dargestellt.

| Beispiele für echte und angenommene Materialverluste   | Lösung  |
|--|---|
| Tatsächliche Verluste sowie ihre Ursachen und Auftrittsorte bleiben unerkannt, weil eine Überwachung der Ein- und Ausgänge in allen Stadien des Prozesses von der Rohstoffannahme bis zur Produktabgabe und nachsorgenden Behandlungen fehlt | Erstellen einer Stoffbilanz   |
| Berechnete spezifische Erträge zeigen, dass die Menge des pro Rohstoffeinheit erzeugten Produkts nicht gleich bleibt, bzw. relative Erträge zeigen, dass der prozentuale Anteil des in Produkt umgewandelten Rohstoffs nicht gleich bleibt   | Erträge berechnen, Kennzahlen festlegen und auf ihre Einhaltung achten                            |
| Angenommene oder tatsächliche Über- oder Unterbefüllung führt zu Überlaufen oder nicht vorgabengerechtem Produkt   | Messgeräte installieren, verwenden und regelmäßig kalibrieren                                     |
| Übermäßiger oder zu geringer Einkauf führt zum Verderb ungenutzten Lagerguts   | genaue Verzeichnisse führen   |
| Änderungen des Materialvolumens aufgrund von Temperaturänderungen werden nicht erkannt   | Verwendung von Umrechnungsfaktoren zur Berücksichtigung von temperaturbedingten Volumenänderungen |

**Tabelle 4.4: Beispiele für Ursachen von Materialverlusten und Methoden zur Pflege eines genauen Bestandsverzeichnisses**  
 [11, Environment Agency of England and Wales, 2000]

Das Prozessfließdiagramm einer Anlage zur Flüssigmilchproduktion lässt sich beispielsweise um spezifische Stoffbilanzen erweitern, die eine Übersicht darüber geben, wo die Hauptmilchverluste auftreten, wie in Abbildung 4.7 dargestellt.

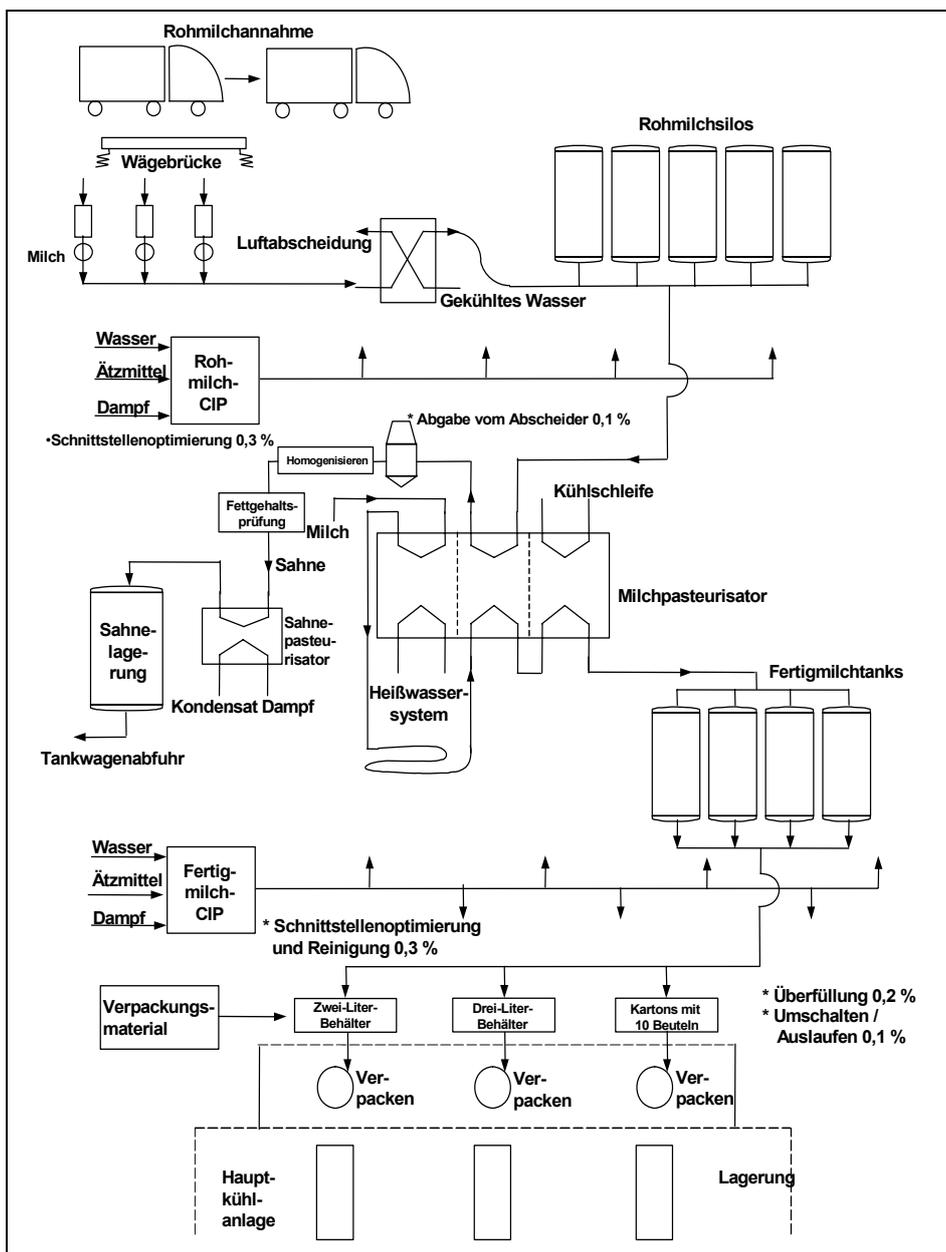


Abbildung 4.7: Ausführliches Prozessfließdiagramm für die Flüssigmilchproduktion [11, Environment Agency of England and Wales, 2000]

Das obige Prozessfließdiagramm zeigt, dass der Gesamtverlust an Rohmilch in dem Prozess bei 0,7 % bis 1,0 % liegt. Dieser Wert wird als Hinweis auf die Anwendung bester Praktiken in der Branche angesehen. Tabelle 4.5 zeigt die in dem Diagramm ausgewiesenen Hauptbereiche der Abfallmilchentstehung.

|  |       |
|--|-------|
| Rohmilch-CIP und entsprechende Anlage  | 0,3 % |
| Verarbeitung – hauptsächlich Abgabe aus Zentrifugalabscheider  | 0,1 % |
| Fertigmilch-CIP und entsprechende Anlage   | 0,3 % |
| Überfüllung beim Abpacken  | 0,2 % |
| Umschalten/Auslaufen beim Abpacken   | 0,1 % |
| Rohmilchverlust insgesamt*   | 1,0 % |
| *Von dieser Analyse ausgenommen ist sämtliche regenerierte Prozessmilch; das sind normalerweise 1,5 %, die in Abfallmeldesystemen aufgeführt werden. |       |

Tabelle 4.5: Hauptbereiche der Entstehung von Abfallmilch

**4.1.6.3 Schritt 3: Bewertung von Zielsetzungen**

Die Zielsetzungen des Vermeidungs- und Verminderungsprogramms werden auf der Basis der in Schritt 2 erstellten Analyse bewertet. Zu diesen Zielsetzungen zählen Reduktionszielwerte, Grenzen und Zeitrahmen. Die Zielsetzungen müssen messbar und in einem Programmplan zeitlich festgelegt sein, sodass sie dazu verwendet werden können, den planmäßigen Verlauf des Programms zu überwachen. Im weiteren Verlauf des Verfahrens können diese Zielsetzungen überarbeitet werden, wenn das eigentliche Vermeidungs- und Verminderungsprogramm implementiert wird (siehe Schritt 6).

**4.1.6.4 Schritt 4: Aufzeigen von Möglichkeiten zur Vermeidung und Verminderung**

Zum Aufzeigen von Maßnahmen zur Vermeidung und Verminderung von Wasser- und Energieverbrauch sowie Abfallerzeugung können verschiedene Ansätze verwendet werden, z. B. Brainstorming, interne Untersuchungen, externe Beratung und Pinch-Technologie (siehe Abschnitt 4.1.6.4.1).

Die Identifizierung von Möglichkeiten zur Vermeidung und Verminderung hängt von Wissen und Kreativität der Mitglieder des Projektteams und anderer Mitarbeiter ab, was natürlich wiederum im Wesentlichen aus deren eigener Erfahrung kommt. Durch die sorgfältige Analyse der Ursachen eines Problems lassen sich oft mehrere Möglichkeiten finden.

Alternativ können sich auch Personen aus verschiedenen Teilen der Organisation treffen, um Lösungen für spezifische Probleme in einer offenen, nicht einschüchternden Atmosphäre in Brainstorming-Sitzungen zu besprechen.

Zusätzliche Ideen lassen sich durch das Hinzuziehen eines Beraters mit speziellem Expertenwissen gewinnen, der eine Besichtigung des Betriebs vornimmt.

So gibt es in der Nahrungsmittelproduktion beispielsweise viele Maßnahmen, die zur Verringerung der verwendeten Wassermenge eingesetzt werden können, wie z. B. die Vermeidung von Wasserverbrauch, die Optimierung der Prozesssteuerung (siehe Abschnitt 4.1.8), die Kreislaufführung und Wiederverwendung von Wasser, gute handwerkliche Praxis und Wartung (siehe Abschnitt 4.1.5). In Tabelle 4.6 werden Beispiele möglicher Wassersparmaßnahmen aufgezeigt.

| <b>Wassersparmaßnahme</b>                         | <b>Typische Reduzierung des Prozessverbrauchs (%)</b> |
|---|---|
| Wasserwiederverwertung im geschlossenen Kreislauf | bis zu 90   |
| CIP (neu)   | bis zu 60   |
| Wiederverwendung von Waschwasser                  | bis zu 50   |
| Gegenstromspülen, z. B. in CIP                    | bis zu 40   |
| Gute handwerkliche Praxis                         | bis zu 30   |
| CIP-Optimierung                                   | bis zu 30   |
| Aufrüstung von Sprüh-/Spritzdüsen                 | bis zu 20   |
| Bürsten/Abzieher                                  | bis zu 20   |
| Automatische Abschaltung                          | bis zu 15   |

**Tabelle 4.6: Normalerweise erzielbare Reduzierung des Wasserverbrauchs [23, Envirowise (UK) and Dames & Moore Ltd, 1998]**

Angaben zufolge ist es nötig, dass bei der Identifizierung von Energieeffizienzmaßnahmen Produktionsprozesse, Versorgungsleistungen und Gebäude getrennt betrachtet werden. Verschiedene öffentlich zugängliche Quellen liefern reichhaltige Informationen zu Energieeffizienztechniken. Die verfügbaren Techniken sind jedoch stark vom jeweiligen Standort und der Art des angewandten Verfahrens abhängig. Im Endeffekt sind die Gesamtenergieeinsparungen normalerweise das Ergebnis kleiner Einsparungen in mehreren Bereichen. So sind beispielsweise durch verbesserte Haushaltung (siehe Abschnitt 4.1.7.11) und Feineinstellungen Einsparungen von bis zu 25 % möglich. Zusätzliche Einsparungen lassen sich durch den Einsatz energieeffizienterer Geräte, Wärmerückgewinnung und die Anwendung kombinierter Erzeugung von Wärme und Strom (KWK) erzielen

(siehe Abschnitt 4.2.13.1.1). Ein als Beispiel angeführter Nudelhersteller gab an, dass die Verbesserung der Energieeffizienz eines seiner Heizkessel von 85 % auf 90 % zu einer Verringerung der CO<sub>2</sub>-Emissionen um 5,56 % (bei Verwendung eines Umrechnungsfaktors von 84,6 kg CO<sub>2</sub>/GJ) führen könnte.

Viele Maßnahmen, die zur Reduzierung der Umweltauswirkungen angewendet werden können, z. B. die Verringerung des Energieverbrauchs, haben keinerlei Auswirkungen auf andere verschmutzende Emissionen der Anlage. Solche Maßnahmen können als „eigenständig“ betrachtet und entsprechend ihrem jeweiligen wirtschaftlichen Nutzen und Umweltnutzen bewertet werden.

Andererseits können manche Maßnahmen zu positiven oder negativen Auswirkungen auf andere Umweltaspekte führen, und in diesen Fällen müssen die umfassenderen Umweltauswirkungen berücksichtigt werden. Im Fall von Kompromissen, z. B. zwischen Energieverbrauch und anderen Umweltzielsetzungen, muss eine Bewertung unter Berücksichtigung der Kosten und der Umweltvorteile durchgeführt werden, damit die Umsetzung angemessener Maßnahmen begründet werden kann.

#### 4.1.6.4.1 Pinch-Technologie

##### Beschreibung

Die Bezeichnung Pinch-Technologie wurde als Methodik in Prozessdesign und Energieeinsparung eingeführt. Ursprünglich entwickelt wurde sie jedoch für den Einsatz in den Bereichen Wasserverbrauch und Abfallreduzierung.

Die Energie-Pinch-Technologie ist ein Analysenverfahren, das die beste Nutzung der Wärmeübertragung von warmen Strömen, die Kühlung erfordern, auf kühle Ströme, die Erwärmung erfordern, untersucht. Eine Pinch-Analyse bietet einen systematischen Ansatz zur Untersuchung von Energienetzen und zur Verbesserung der Energieeffizienz von Industrieprozessen. Die Analyse verwendet die grafische Darstellung der Energieströme in den Prozess- und Versorgungsströmen, um die für die Erfüllung der Prozessanforderungen benötigten Mindestbedarf an Energie und Energiesystemen zu ermitteln. Bei der Methode werden Temperatur-Enthalpie-Diagramme zur Beschreibung der für eine Wärmeübertragung zur Verfügung stehenden warmen und kalten Ströme verwendet. Die Summe der warmen und kalten Ströme in einem Prozess können in ein ähnliches Diagramm eingezeichnet werden, aus dem sich die Pinch-Temperatur bestimmen lässt. Anhand dieser Informationen lässt sich herausfinden, wo und in welchem Ausmaß Wärmerückgewinnung in dem Prozess möglich ist. Außerdem lassen sich so die Minimalanforderungen für die Wärme- und für die Kälteversorgung bestimmen. Zur Erfüllung dieses Mindestenergiebedarfs wird ein Wärmetauschernetz installiert. Die Pinch-Analyse liefert das optimale Design dafür.

Die Wasser-Pinch-Technologie kann ein leistungsstarkes Werkzeug zur Erkennung von Möglichkeiten für die Wiederverwendung, Wiederverwertung und Regenerierung innerhalb einer Anlage oder eines Prozesses sein. Sie verwendet komplexe Algorithmen zur Identifizierung und Optimierung der besten Möglichkeiten für die Wiederverwendung und Regenerierung von Wasser sowie für die Abwasserbehandlung. Die Grundkonzepte für die Wärmerückgewinnung gelten analog auch hier. Wasserströme und deren Gehalt an wasserverschmutzenden Stoffen werden berücksichtigt, woraus sich sogenannte Quellen und Senken ergeben.

##### Erreichbare Umweltvorteile

Geringerer Energieverbrauch und damit geringere Abluftemissionen. Weniger an die Umgebungsluft oder an das Wasser abgegebene Abwärme. Maximierung der Wiederverwendung von Wasser unter Berücksichtigung der Qualitätserfordernisse der jeweiligen Anwendung. Minimierung des Zusatzes von Frischwasser und der Abgabe von Abwasser. Minimierung von Abfällen.

##### Betriebsdaten

In einer als Beispiel genannten Raffinerie für Speiseöle wurde die Pinch-Technologie eingesetzt, um zu untersuchen, ob ein neues Raffiniervorgang energieeffizienter wäre als das Vorgängerverfahren, bei dem für die Prozesswärme Dampf und für die Kühlung Flusswasser verwendet wurde. Die Analyse ergab, dass der Pinch-Punkt bei 55 °C lag; daraus ließ sich eine Strategie zur Wärmerückgewinnung formulieren. Sie zeigte ferner, dass die bestehenden Chargenprozesse dazu führen würden, dass Wärmeverfügbarkeit und Wärmebedarf zu unterschiedlichen Zeitpunkten auftreten, was einen direkten Wärmeaustausch zwischen vielen der warmen und kalten Prozessströme unpraktisch machte. Vor der Durchführung von Prozessintegrationsprojekten war also ein Medium für die Wärmeübertragung bzw. -speicherung erforderlich. Es wurde ein Wärmerückgewinnungsnetz entwickelt, das Wasser für die Übertragung und Speicherung von Wärme nutzte. Diese Vorgehensweise

war sehr erfolgreich, und weder die Produktionskapazität noch die Produktionsflexibilität wurde beeinträchtigt. Außerdem ermöglichte die Verwendung des Versorgungssystems, das auf drei Wassertemperaturen, nämlich 30 °C, 55 °C und 95 °C, und vier thermischen Tanks basierte, die erfolgreiche Integration nicht zusammenhängender Chargenprozesse.

Nach zwei Jahren führte die Speiseölraffinerie eine aktualisierte Pinch-Analyse durch, aus der sich ergab, dass der Pinch-Punkt sich verlagert hatte; daraufhin wurden operative Veränderungen erwogen. Nach der Pinch-Analyse verringerte sich der Energieverbrauch um 35 %; die CO<sub>2</sub>-Emissionen sanken um 16.700 t/Jahr. Außerdem wurde weniger Abwärme in das Fließgewässer abgegeben.

### Anwendbarkeit

Die Pinch-Analyse wird erfolgreich in der chemischen Prozessindustrie und in Raffinerien eingesetzt. Sie kann auch ein nützliches Werkzeug für größere und komplexere Anlagen in der Nahrungsmittelproduktion sein. In relativ einfachen Betrieben führt sie nicht zu mehr oder besseren Möglichkeiten, als sie sich auch mit anderen Methoden finden lassen. Die Methode ist außerdem auf Chargenprozesse schwer anwendbar und berücksichtigt den Stromverbrauch nicht.

### Wirtschaftlichkeit

Tabelle 4.7 zeigt die für eine als Beispiel genannte Speiseölraffinerie angegebenen Kosten und Einsparungen beim Einsatz der Pinch-Technologie.

| <b>Kosten der Pinch-Analyse (EUR)</b>                 |                  |
|---|------------------|
| Beratungsgebühren für die Pinch-Analyse               | 32.000           |
| Eigene Personalkosten für die Pinch-Analyse           | 16.000           |
| Umsetzung der Empfehlungen aus der Pinch-Analyse      | 3.066.000        |
| Verbindung zur Nachbaranlage zwecks Wärmeabgabe       | 203.000          |
| Jährliche Betriebskosten des Wasserversorgungssystems | 84.000           |
| <b>Gesamtkosten</b>                                   | <b>3.401.000</b> |
| <b>Einsparungen durch Pinch-Analyse (EUR)</b>         |                  |
| Einsparungen bei Energiekosten                        | 1.145.000        |
| Verkauf der überschüssigen Wärme                      | 90.000           |
| <b>Nettoeinsparungen</b>                              | <b>1.235.000</b> |

**Tabelle 4.7: Für eine als Beispiel genannte Speiseölraffinerie angegebene Kosten und Einsparungen beim Einsatz der Pinch-Technologie**

### Anlässe für die Umsetzung

Kostenreduktion.

### Beispielanlagen

Eine Speiseölraffinerie im Vereinigten Königreich verwendete die Pinch-Technologie zur Senkung ihrer Energiekosten.

### Referenzliteratur

[1, CIAA, 2002, 237, Caddet, 1999]

#### **4.1.6.5 Schritt 5: Erstellung einer Evaluierungs- und Machbarkeitsstudie**

Zweck der Evaluierungs- und Machbarkeitsstudienphase ist die Evaluierung der vorgeschlagenen Optionen und die Auswahl derjenigen, die am besten für eine Umsetzung geeignet sind. Alle Möglichkeiten werden hinsichtlich ihrer technischen, wirtschaftlichen und umweltrelevanten Aspekte bewertet. Wie tiefgehend die Studie ist, hängt von der Art der Option ab.

Die einfachste und schnellste Methode zur Bewertung der verschiedenen Optionen besteht meistens darin, ein Projektteam aus Mitarbeitern und Führungspersonal zu bilden, das die verschiedenen Lösungen einzeln bespricht. Dadurch lässt sich ein guter Eindruck davon gewinnen, welche Projekte machbar sind und welche Zusatzinformationen für eine gründlichere Evaluierung benötigt werden.

Technische Evaluierung

Bevor über möglicherweise komplizierte und teure Maßnahmen entschieden wird, müssen die potenziellen Auswirkungen der vorgeschlagenen Optionen auf Produkte, Produktionsprozesse, Gesundheit und Sicherheit eingeschätzt werden. Außerdem können Labor- oder Pilotversuche erforderlich sein, wenn bestehende Prozesse durch die gewählte Option wesentlich verändert werden.

Wirtschaftliche Evaluierung

Ziel dieses Schrittes ist die Evaluierung der Kosteneffektivität der vorgeschlagenen Optionen. Bei der Durchführung der wirtschaftlichen Evaluierung werden die Kosten der Veränderung gegen die möglicherweise entstehenden Umweltvorteile und die potenziellen finanziellen Einsparungen abgewogen. In Wirklichkeit entscheidet die wirtschaftliche Durchführbarkeit oft darüber, ob eine Option umgesetzt wird oder nicht.

Umweltevaluierung

Zweck der Umweltevaluierung ist die Bestimmung der positiven und negativen Umweltauswirkungen der Option. In vielen Fällen sind Umweltvorteile, insbesondere ein geringerer Wasser- oder Energieverbrauch sowie eine geringere Abfallerzeugung, offensichtlich. In manchen Fällen kann es nötig sein abzuschätzen, ob beispielsweise ein erhöhter Stromverbrauch den Umweltnutzen eines geringeren Wasserverbrauchs aufwiegt. Ein Beispiel für eine Technik mit positiven und negativen Umweltauswirkungen, d. h. mit verringertem Wasserverbrauch und erhöhtem Stromverbrauch, ist der Ersatz eines Durchlaufkühlsystems durch ein Kühlsystem mit geschlossenem Kreislauf und Kühlgeräten.

**4.1.6.6 Schritt 6: Umsetzung des Vermeidungs- und Verminderungsprogramms**

Durch die Verwendung eines Eingriffsplans kann sichergestellt werden, dass die ausgewählten Optionen umgesetzt werden. Der Eingriffsplan kann die durchzuführenden Tätigkeiten angeben, die erforderlichen Ressourcen, die für die Durchführung verantwortlichen Personen sowie die Termine für die Durchführung. Es ist wichtig, die Effektivität der umgesetzten Maßnahmen einzuschätzen und ihre Auswirkungen zu überwachen und regelmäßig zu überprüfen (siehe Abschnitt 4.1.6.7).

Zur Umsetzung der Optionen muss ein Umsetzungs- und Eingriffsplan vorbereitet und eingesetzt werden. Dafür wird ein Schritt-für-Schritt-Ansatz empfohlen. Der Eingriffsplan muss realistische und erzielbare Reduktionsziele für Verbrauch und Emissionen enthalten, denen die obere Führungsebene zugestimmt hat. Die Beteiligung des gesamten Personals an der Umsetzung des Eingriffsplans sowie regelmäßige Informationen an das Personal über die Ergebnisse tragen dazu bei, den Schwung des Programms aufrechtzuerhalten und die Mitarbeiter dazu zu ermutigen, sich Gedanken über zukünftige Ideen und Initiativen zu machen. Fortschritte sollten regelmäßig mit den angestrebten Zielen abgeglichen werden.

So sind beispielsweise folgende Schritte bei der Zielwertsetzung für Energieeffizienzmaßnahmen unabdingbar:

- Aufzeichnung des Energieverbrauchs in regelmäßigen Abständen
- Betrachtung der Beziehung zwischen Energieverbrauch und Produktionstätigkeiten und/oder anderen relevanten Parametern
- Einführung von Zielvorgaben für den Energieverbrauch
- Vergleich des tatsächlichen Energieverbrauchs mit den Zielvorgaben
- Berichterstattung
- Durchführung von Maßnahmen, falls der tatsächliche Energieverbrauch erheblich von den Zielvorgaben abweicht

Das Bestimmen realistischer Zielvorgaben ist nicht immer einfach. Ein möglicher Ansatz besteht darin, eine Zahl unterhalb des Durchschnittsniveaus zu wählen, z. B. 10 % darunter. Ein anderer Ansatz zur Bestimmung des minimalen Energieverbrauchs geht von den technischen Daten für die verschiedenen Teile der Prozesslinien aus.

**4.1.6.7 Schritt 7: Laufende Überwachung durch Messungen und Sichtprüfungen**Beschreibung

Es ist wichtig, die Effektivität der umgesetzten Maßnahmen für die Minimierung von Verbrauchs- und Emissionswerten zu einschätzen und ihre Auswirkungen zu überwachen und regelmäßig zu überprüfen. Die

zu überwachenden Parameter sind abhängig von den Produktionsprozessen und den in der Anlage verwendeten Rohstoffen und Chemikalien. Die Häufigkeit, mit der ein Parameter überwacht wird, kann je nach Bedarf und Risiken für die Umwelt sowie gewähltem Überwachungsverfahren stark unterschiedlich ausfallen. Wird ein Problem erkannt, können korrigierende und vorbeugende Maßnahmen ergriffen werden. Auch die Einführung neuer Produkte oder Prozesse kann sich positiv oder negativ auf die Verbrauchs- oder Emissionswerte auswirken, sodass die Techniken zu deren Reduzierung unter Umständen angepasst werden müssen.

Die Überwachung kann, je nach Einzelfall, auf unterschiedliche Art und Weise erfolgen und sowohl die Messung physikalischer und chemischer Parameter als auch Sichtprüfungen umfassen. Wenn die Überwachung laufender Abwasseremissionswerte erforderlich ist, sind entsprechende Messungen nötig. Regelmäßige und häufige Sichtprüfungen können die Wasserverbrauchsmessungen ergänzen. So kann beispielsweise die Einrichtung eines Routineprogramms zur visuellen Überprüfung des Umgangs mit Wasser und Abwasser in der Anlage Teil eines Programms zur Erkennung von Bereichen mit Verbesserungsmöglichkeiten und Wartungsanforderungen sein.

Weitere Informationen zur Überwachung finden sich im Referenzdokument über die allgemeinen Überwachungsgrundsätze [96, EC, 2003].

### Erreichbare Umweltvorteile

Durch laufende Überwachung kann die Wirksamkeit der gewählten Maßnahmen regelmäßig überprüft werden; so wird erkennbar, ob die gesetzten Zielvorgaben wie z. B. Verbrauchs- und Emissionswerte, erreicht werden, und Fehlleistungen können identifiziert und behoben werden. Die Überwachung zeigt außerdem Trends auf und kann auf Bereiche verweisen, die Priorität für Verbesserungen haben.

### Betriebsdaten

Ein als Beispiel genannter Stärkehersteller verarbeitet Mais in Stärke, Stärkederivate und Glukose. Die Produkte werden sowohl in der Lebensmittelbranche als auch in anderen Branchen verwendet. Durch systematische Überwachung und Analyse des Prozesses möchte das Unternehmen den Energieverbrauch der Anlage verringern. Die jährlichen Einsparungen entsprechen 3 Millionen m<sup>3</sup> Erdgas (95 TJ), was eine Reduktion um ungefähr 10 % bedeutet.

Zuvor war der Energieverbrauch in der Stärkeanlage aus zufälligen Messungen oder aus vom Energielieferanten gemachten Angaben abgeleitet worden. Der Energieverbrauch der einzelnen Produktionsstadien und der jeweiligen Produkte wurde aus diesen Daten berechnet. Daraus ließ sich lediglich ein Überblick über den tatsächlichen Energieverbrauch gewinnen, der allerdings nicht ausreichte, um die Energieeffizienz der Anlage zu verbessern. Es wurde daher ein Überwachungssystem installiert, mit dem der spezifische Energieverbrauch mehrerer Prozessstadien gemessen wird. Der Produktionsprozess wurde in einzelne Arbeitsbereiche unterteilt. Jeder Bereich umfasst die Herstellung eines bestimmten Produkts oder einer Produktgruppe. Die Energieströme in allen Modulen werden in Echtzeit gemessen. Die Messungen ermöglichen die Bestimmung sowohl des jeweiligen Energiestroms zum Messzeitpunkt als auch des Verbrauchs über einen längeren Zeitraum.

Mit dem neuen System ist es möglich, den tatsächlichen mit dem theoretischen Energieverbrauch der Stärkeanlage zu vergleichen, wodurch der Prozess im Fall ungünstiger Unterschiede optimiert werden kann. Außerdem vergleicht das System den gemessenen Energieverbrauch mit dem vergleichbarer Arbeitsbereiche in Schwesterunternehmen und kann Arbeitsbereiche gemäß dem günstigsten Design verändern.

Mit dem neuen Überwachungssystem werden laufend die Wasser-, Dampf-, Erdgas- und Elektrizitätsströme der Module gemessen. Die erfassten Daten werden an eine zentrale Verarbeitungseinheit übertragen und in Tabellen und Diagramme umgewandelt, die an Interessenten verteilt werden.

In seiner vorliegenden Form zeichnet das System nur den tatsächlichen Energieverbrauch der Anlage auf und dokumentiert diesen. Die Berechnung des spezifischen Energieverbrauchs, bezogen auf die Produktion der Anlage, wird noch manuell durchgeführt. Die Datenanalyse beruht auf Vergleichen mit historischen Daten für den Energieverbrauch unter ähnlichen Bedingungen.

Eine Beispiel-Molkerei im Vereinigten Königreich hat ein computerbasiertes Überwachungs- und Zielsetzungssystem installiert, um Kosten zu senken und die Rentabilität zu verbessern. In der Molkerei wurden mehrere Messgeräte für den Strom-, Öl- und Wasserverbrauch installiert. Die Ablesewerte der Messgeräte wurden in das System eingegeben, das die Daten so darstellt, dass das Unternehmen Bereiche, an denen

Verschwendung auftritt, erkennen und korrigierend eingreifen kann. Die Funktionsweise des Systems hat sich in diesem Fall sehr bewährt, da laufend Verbesserungen der Energieeffizienz vorgenommen werden. Es wurden erhebliche Einsparungen im Energie- und Versorgungsbereich erzielt. Diese Einsparungen, die bei geringen Investitionskosten erreicht wurden, sind teilweise auf die große Motivation des Personals auf allen Ebenen zurückzuführen.

#### Anwendbarkeit

In der Nahrungsmittelproduktion in vielen Bereichen anwendbar.

#### Wirtschaftlichkeit

Die Gesamtinvestitionskosten der Stärke-Beispielanlage beliefen sich auf 700.000 EUR. Bei einem Gaspreis von 0,095 EUR/m<sup>3</sup> betragen die jährlichen Einsparungen 284.000 EUR. Das entspricht einem Amortisationszeitraum von ungefähr 2,5 Jahren.

#### Anlässe für die Umsetzung

Geringere Kosten und bessere Rentabilität.

#### Beispielanlagen

Ein Stärkehersteller in den Niederlanden und eine Molkerei im Vereinigten Königreich.

#### Referenzliteratur

[1, CIAA, 2002, 96, EC, 2003, 150, Unione Industriali Pastai Italiani, 2002, 181, EC, 2003, 240, CADDET, 1997]

## **4.1.7 Techniken für das Produktionsmanagement**

### **4.1.7.1 Produktionsplanung zur Reduzierung der Abfallentstehung und Reinigungshäufigkeit**

#### Beschreibung

Gut durchdachte Produktionspläne, durch die die Anzahl der Produktwechsel und damit der „Zwischenreinigungen“ gesenkt wird, können die Abfallentstehung, den Wasserverbrauch und den Abwasseranfall reduzieren. Wenn sich dasselbe Produkt in nur einer Charge anstatt in zwei oder mehr Durchgängen herstellen lässt, kann die Zahl der Umstellungen gesenkt werden. Mit der Produktionsabfolge können auch Anzahl und Ausmaß der erforderlichen Reinigungen beeinflusst werden.

Wenn in einer Anlage mehrere unterschiedliche Produkte oder dasselbe Produkt in unterschiedlichen Geschmacksrichtungen oder Farben hergestellt werden, so ist in Abhängigkeit von dem Unterschied bei den Produktvorgaben und von dem Kreuzkontaminationsrisiko beim Produktwechsel eine Reinigung von Geräten und Anlage erforderlich. Aus Gründen der Lebensmittelsicherheit können diese Reinigungen wichtig sein, z. B. beim Wechsel von Inhaltsstoffen, gegen die manche Menschen allergisch sind, wie z. B. Erdnüsse bei der Herstellung von Fertigmahlzeiten. Auch aus Geschmacks- und Farbgründen kann die Reinigung wichtig sein, z. B. bei der Umstellung des Joghurtgeschmacks von Brombeere auf Pfirsich.

Wenn beim Produktwechsel Rückstände von den Geräten entfernt werden müssen, können diese unter Umständen in Nebenprodukten verwendet werden; andernfalls sind sie als Abfall zu entsorgen. Wenn die Zahl der Umstellungen minimiert wird, kann die Menge der entfernten Rückstände reduziert und der Gesamtanteil der Rohstoffe, die im Endprodukt Verwendung finden, maximiert werden. Ebenso wird auch die bei „Zwischenreinigungen“ aufgewandte Menge an Wasser, Energie und Chemikalien minimiert.

#### Erreichbare Umweltvorteile

Geringerer Verbrauch von Wasser, Energie und Chemikalien und geringeres Abwasser- und Abfallaufkommen.

#### Anwendbarkeit

In Anlagen der Nahrungsmittelproduktion anwendbar, in denen Geräte für mehr als ein Produkt verwendet werden und Produktvermischungen aus rechtlichen Gründen, aus Gründen der Lebensmittelsicherheit oder aus Qualitätsgründen vermieden werden müssen.

### Anlass für die Umsetzung

Geringerer Verbrauch von Wasser, Energie und Chemikalien und Senkung des Abwasser- und Abfallaufkommens sowie der damit verbundenen Kosten.

### **4.1.7.2 Anlieferung von Material in großen Mengen**

#### Beschreibung

Viele Materialien, die entweder direkt im Prozess oder für Hilfstätigkeiten wie die Reinigung verwendet werden, können in großen Mengen angeliefert und in Silos oder Mehrwegbehältern gelagert oder direkt in Mehrwegverpackungen anstatt in Einwegverpackungen verwendet werden.

#### Erreichbare Umweltvorteile

Einsparung von Verpackungsmaterialien und mögliche Wiederverwendung benutzter Materialien.

#### Medienübergreifende Effekte

Wenn leere Behälter ungereinigt zurückgegeben werden, treten keine medienübergreifenden Auswirkungen auf.

#### Betriebsdaten

Viele Rohstoffe in der Nahrungsmittelproduktion werden in Tankwagen angeliefert und bis zur direkten Verwendung im Prozess in Silos gelagert. Beispiele sind Getreide in der Müllereibranche, in der Braubranche und in der Tierfutterproduktion, Mehl in der Brot- und Gebäckherstellung, Grieß in der Nudelherstellung, Zucker in der Süßwarenherstellung und Milch in der Milch-, Milchpulver-, Butter-, Käse-, Joghurt- und sonstigen Molkereiprodukten. Die Silolagerung wird so geplant, dass feste Materialien, die zuerst angeliefert und oben am Silo eingefüllt werden, auch unten wieder zuerst aus dem Silo entnommen werden. Flüssigkeiten wie Milch werden chargenweise verarbeitet. Haltbarkeitsprobleme lassen sich daher vermeiden, wenn Annahme, Lagerung und Verbrauch entsprechend überwacht und geregelt werden.

In der Nahrungsmittelproduktion werden für die Reinigung verwendete Chemikalien, wie z. B. Natronlauge, grobenteils entweder in Tanklastzügen geliefert und in Großtanks gelagert, oder sie werden in mittelgroßen Behältern geliefert und aus diesen direkt verwendet. Das gilt insbesondere für Chemikalien, die für die CIP-Reinigung verwendet werden, wie beispielsweise in Molkereien und Brauereien.

Bei der Verarbeitung von Hackfleisch werden Gewürze oft in voreingewogenen Mengen verwendet. Sie werden üblicherweise in Kunststoffbags gelagert, die nach dem Entleeren entsorgt werden. Zur Reduzierung des Gebrauchs von Kunststoffverpackungen lassen sich Gewürze automatisch aus einem Vorratsbehälter dosieren.

#### Anwendbarkeit

Vielorts anwendbar, wo Inhaltsstoffe oder Reinigungsmaterial in großen Mengen verwendet werden.

#### Wirtschaftlichkeit

Es ist im Allgemeinen billiger, Produktionseinsatz- und Hilfsstoffe (z. B. Chemikalien) in großen Mengen zu kaufen als in kleinen.

#### Anlass für die Umsetzung

Programme zur Rückgewinnung von Produktionsverlusten und Verpackungsabfall sowie rechtliche Regelungen zu Gesundheit und Sicherheit, die darauf abzielen, den Kontakt mit gesundheitsgefährdenden Stoffen und durch manuelle Handhabung bedingte Unfälle zu reduzieren.

#### Beispielanlagen

Weit verbreitet in der Nahrungsmittelproduktion, z. B. in Getreidemühlen, Mehlmühlen, Bäckereien, Konditoreien, Nudelherstellungsbetrieben und Molkereien.

#### Referenzliteratur

[31, VITO, et al., 2001, 41, Nordic Council of Ministers, 2001]

### 4.1.7.3 Minimierung der Lagerzeiten verderblicher Stoffe

#### Beschreibung

Die Lagerzeit von Rohstoffen, Zwischenprodukten, Nebenprodukten, Produkten und Abfällen kann so kurz wie möglich gehalten werden. Je nach Art, Lagerfähigkeit, inhärenten Geruchseigenschaften und der Geschwindigkeit, mit der sie biologisch abgebaut und zum Geruchsproblem werden, kann dabei Kühlung eingesetzt werden. Durch die schnellstmögliche Verarbeitung von Produkten und die damit verbundene Verkürzung der Lagerzeiten lassen sich Qualität und Ausbeute, und somit die Rentabilität des Prozesses, steigern.

Verluste können reduziert werden, wenn die Lagerbestände zwecks Vermeidung von Alterung/Verderb so gering wie möglich gehalten und die Materialien so schnell wie möglich verarbeitet werden. Dazu gehört die Planung und Überwachung der Beschaffung, Produktion und der Abgabe von Material und fertigen Produkten sowie von Halbfertigprodukten und Abfall. Durch die schnelle Verwendung von Rohstoffen oder teilweise verarbeiteten Materialien oder durch schnelleren Versand der Produkte und Nebenprodukte können Verluste durch Zersetzung und auch der Kühlbedarf verringert werden. Die Trennung von Abfallstoffen und der schnellstmögliche Abtransport von Abfällen aus der Anlage können Geruchsprobleme verhindern.

Unter Berücksichtigung von Hygiene, Lebensmittelsicherheit, Haltbarkeitsdauer und Produktqualität lässt sich bei Behandlungen, die eine Erwärmung umfassen, Energie sparen, indem die Nahrungsmittel vor dieser Behandlung aus dem Kühllager entnommen werden und somit ihre Temperatur vorher ansteigen kann. Ebenso kann beim Kühlen Energie gespart werden, wenn verhindert wird, dass Nahrungsmittel, die mit Kälte behandelt werden, sich vorher erwärmen.

#### Erreichbare Umweltvorteile

Weniger Abfälle an Rohstoffen, teilweise verarbeiteten Stoffen und Endprodukten. Geringere Geruchsemissionen und geringerer Energieverbrauch für Kühlung oder Erwärmung<sup>5</sup>.

#### Betriebsdaten

Die Optimierung von Materialverlusten und Kühlanforderungen erfordert die Zusammenarbeit der Lieferanten von Rohstoffen und Zusatzstoffen sowie von Hilfsmaterialien, die für den Prozess erforderlich sind, wie z. B. Verpackungsmaterial. Es kann vertraglich festgelegt werden, dass der an den Lieferanten zu zahlende Preis von der Qualität beispielsweise des gelieferten Rohstoffs abhängig ist.

Da es sich bei Obst und Gemüse um weiche essbare pflanzliche Produkte mit relativ hohem Wassergehalt handelt, sind diese in frischem Zustand verderblich. Verluste lassen sich durch die sofortige Verarbeitung, d. h. durch Vermeidung einer Lagerung, vermeiden.

Fisch verdirbt im Vergleich zu anderen Lebensmitteln schnell und muss im Allgemeinen vom Moment des Fangs an entweder gefrostet oder auf Eis gelagert werden, damit Zersetzung und Geruchsemissionen vermieden und Produktqualität und -ertrag optimiert werden. Auch Produktverluste tragen zu Belastungen der festen und flüssigen Abfälle bei. Durch schnelle Verarbeitung werden Abfälle, Gerüche und Energieverbrauch für Kühlung und Eisproduktion reduziert. Außerdem kann der Fisch dann für Produkte verwendet werden, die einen höheren Preis erzielen, z. B. für Frischfisch, gepökelte oder geräucherte Filets.

Aufgrund ihrer leichten Verderblichkeit wird Milch in großen Milchkühlern im landwirtschaftlichen Betrieb gelagert. Durch schnelle Wärmebehandlung und Weiterverarbeitung werden Verluste reduziert.

Wenn Halbfertigprodukte so schnell wie möglich von einem Nahrungsmittelproduktionsbetrieb an den nächsten weitergegeben werden, wo sie weiter verarbeitet werden sollen, lässt sich in der Anlage des Produzenten der Kühlbedarf und in der Anlage des Abnehmers die Abfallmenge reduzieren, indem der Ertrag aus frisch hergestellten Bestandteilen vergrößert wird.

#### Anwendbarkeit

Anwendbar auf Nahrungsmittelproduktionsanlagen, in den verderbliche Materialien gehandhabt, gelagert oder verarbeitet werden.

<sup>5</sup> Anmerkung d. UBA-Bearb.: ...oder Erwärmung.

### Wirtschaftlichkeit

Normalerweise entfällt in der Nahrungsmittelproduktion ein Großteil der Herstellungskosten auf die Rohstoffe. Die wirtschaftlichen Folgen der Abfallentstehung begrenzen sich nicht auf die tatsächlichen Kosten der Abfallentsorgung, sondern erstrecken sich u. a. auch auf die Rohstoff- und Produktverluste und zusätzliche Lohnkosten. Durch das Minimieren der gekühlten Lagerung werden auch die dadurch anfallenden Energiekosten gesenkt.

### Anlass für die Umsetzung

Maximierung von Qualität und Ausbeute aus Rohstoffen, Reduzierung der Abfallentsorgungskosten, geringerer Kühlbedarf und Vermeidung von Geruchsproblemen.

### Beispielanlagen

In der Nahrungsmittelproduktion weit verbreitet.

### Referenzliteratur

[1, CIAA, 2002, 11, Environment Agency of England and Wales, 2000, 31, VITO, et al., 2001, 134, AWARENET, 2002]

## **4.1.7.4 Trockentransport von Feststoffen**

### Beschreibung

Viele Rohstoffe, Koprodukte, Nebenprodukte und Abfälle können ohne den Einsatz von Wasser transportiert werden. Dadurch verringert sich die eingetragene Menge organischer Substanzen ins Wasser, das entweder in eigener oder externer Kläranlage behandelt oder zur Ausbringung auf landwirtschaftliche Nutzflächen verbracht werden müsste.

### Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs. Weniger Abwasseranfall und -verschmutzung. Größeres Rückgewinnungs- und Wiederverwertungspotenzial der im Prozess anfallenden Stoffe, die in vielen Fällen für die Verwertung in Tierfutter verkauft werden können.

### Betriebsdaten

Berichten zufolge können Knochen und Fett vom Entbeinen und Beschneiden von Fleisch trocken gesammelt und transportiert werden. Sie können für den menschlichen Verzehr vorgesehen sein oder auch nicht. So dient beispielsweise in manchen Entbeinungsstationen eine lange Rinne mit einer Förderschnecke unter einem breiten Tisch dazu, Fett und Fleisch abzutransportieren, während die Knochen mit einem Förderband abtransportiert werden. Das abgetrennte Fett kann dann beispielsweise zum Ausschmelzen und die Knochen zur Gelatineproduktion weitergeleitet werden.

Im Fischsektor werden Trockentransportsysteme den Angaben zufolge in verschiedenen Ländern, z. B. in Dänemark und im Vereinigten Königreich, eingesetzt. So lässt sich beispielsweise Wasser sparen, wenn die Haut mittels Vakuum aus Fässern entfernt wird anstatt mit Wasser. Außerdem werden Förderbänder aus feinem Siebmaterial verwendet, um Abfälle aufzufangen und vom Abwasser zu trennen, wodurch dessen CSB sinkt. Andere in diesem Bereich eingesetzte Trockentransportsysteme umfassen die Entfernung von Innereien mittels Vakuum oder mit Förderbändern im Anschluss an das Filetieren und Ausweiden. Auch aus der Verarbeitung von Krebstieren und Muscheln wird über die Verwendung von Trockentransportsystemen für die Sammlung fester Abfälle berichtet. Weitere Informationen dazu finden sich in den Abschnitten 4.7.2.4 bis 4.7.2.6.

Im Obst- und Gemüsesektor werden Trockentransportsysteme für den Abtransport sortierter, unbehandelter oder teilweise behandelter Rohmaterialien, Schalen und Schnittabfälle verwendet. Mechanische Förderbänder können Schwemmrinnen ersetzen. Wo Rinnen unvermeidbar sind, kann das Wasservolumen verringert werden. Der Einsatz von Rinnen kann vorteilhaft sein, wenn er mit Waschvorgängen kombiniert wird. So kann beispielsweise der Transport in Schwemmrinnen mit dem Waschen von Zuckerrüben und von Kartoffeln, die in der Stärkeproduktion verwendet werden, kombiniert werden. Darüber hinaus wird in diesen Prozessen aus dem Rohmaterial extrahiertes Fruchtwasser verwertet. Das Rinnenwasser wird nach einer Behandlung, bei der z. B. Feststoffe wie Erde entfernt werden, wieder verwendet. Auch für den Transport bestimmter Obst- und Gemüsesorten kann die Verwendung von Wasserrinnen nötig sein, um mechanische Beschädigungen beim Transport zu verhindern. Das gilt z. B. für Tomaten, Erbsen, Artischocken und Pilze.

Anwendbarkeit

Anwendbar in den Branchen Fisch, Meeresfrüchte, Fleisch, Obst und Gemüse.

Wirtschaftlichkeit

Geringere Kosten für Wasser und Abwasser. Für das Nebenprodukt lässt sich bei geringerem Wassergehalt ein höherer Preis erzielen, z. B. wenn es als Tierfutter verkauft wird.

Anlass für die Umsetzung

Verbesserung der Hygienestandards. Senkung des Wasserverbrauchs, des Bedarfs an Abwasserbehandlung, des Verbrauchs von Reinigungsmitteln und der Kosten.

Beispielanlagen

Fünf dänische Heringsfiletieranlagen und ein Fischverarbeitungsunternehmen im Vereinigten Königreich.

Referenzliteratur

[13, Environment Agency of England and Wales, 2000, 28, Nordic Council of Ministers, 1997, 31, VITO, et al., 2001, 58, Envirowise (UK), 1999, 74, Greek Ministry for the Environment, 2001, 134, AWARENET, 2002, 147, Lehman N. and Nielsen E.H, 2002, 181, EC, 2003]

**4.1.7.5 Einsatz eines Abfallmanagementteams**Beschreibung

Das Abfallaufkommen kann reduziert werden, wenn Rohstoffe effizient genutzt und parallel dazu Abfälle getrennt werden, damit Materialien, die andernfalls im gemischten Abfall gelandet wären, wieder verwertet werden können. Mit einem Team, das sich ausschließlich der Verringerung der anfallenden Abfallmenge widmet, kann sichergestellt werden, dass die Konzentration auf die Abfallreduzierung auch dann beibehalten wird, wenn im Unternehmen andere Probleme auftreten. Dieser Ansatz kann effektiver sein, wenn er zusätzlich zu der häufiger anzutreffenden Praxis eingesetzt wird, die Verringerung der Abfallmenge bei den Zuständigkeiten der Schichtteams und den Zielen der Qualitätsteams anzusiedeln. Außerdem wird dadurch deutlich gemacht, dass das Unternehmen diesen Bereich ernst nimmt.

Das Team kann beispielsweise an der Planung neuer Geräte, wie z. B. Produktionsstraßen, beteiligt sein. Dadurch wird sichergestellt, dass die Ingenieure schon vom Planungsstadium an nach Möglichkeiten suchen, den Abfall zu verringern.

Tägliche Abfallzahlen können an gut sichtbarer Stelle in der Anlage angezeigt werden, sodass erkennbar ist, wie die Werte im Vergleich zu den Zielwerten ausfallen, welche Ursachen der Abfall hat und was für die Vermeidung weiterer Abfälle getan wird. Ein wöchentlicher Bericht kann an die Unternehmensführung gegeben werden, sodass diese im Gespräch mit ihren Teams hinsichtlich der Abfallfrage mit gutem Beispiel vorangehen und zu weiteren Anstrengungen ermutigen kann.

Aus einer Beispielanlage wird berichtet, dass ein einfaches System eingerichtet wurde, durch das ein Vorfall aufgezeichnet werden konnte, der mehr als 2 Tonnen Abfall verursachte. Es wurden dann eine Untersuchung durchgeführt und Maßnahmen zur Verhinderung einer Wiederholung ergriffen.

Wenn weniger Abfall entsteht, lassen sich auch Hygiene und Sicherheit des Abfallentsorgungsbereichs verbessern.

Es lassen sich außerdem Zielwerte für laufende Verbesserungen vorgeben.

Erreichbare Umweltvorteile

Eine erhebliche Reduktion der entstehenden Festabfallmenge und damit der durch ihre Entsorgung auftretenden Umweltauswirkungen.

Betriebsdaten

Der Einsatz dieser Technik in einer Beispiel-Tierfutteranlage führte über einen Zeitraum von 8 Monaten zu einer Verringerung der Abfallmenge um 50 %. Der geringere Wert konnte dann beibehalten werden. Umweltauswirkungen wurden wesentlich reduziert. Außerdem traten erhebliche Kosteneinsparungen durch die Verminderung von Verlusten und Verschwendung von Rohstoffen auf. Abbildung 4.8 zeigt die Zahlen zum Abfallrückgang.

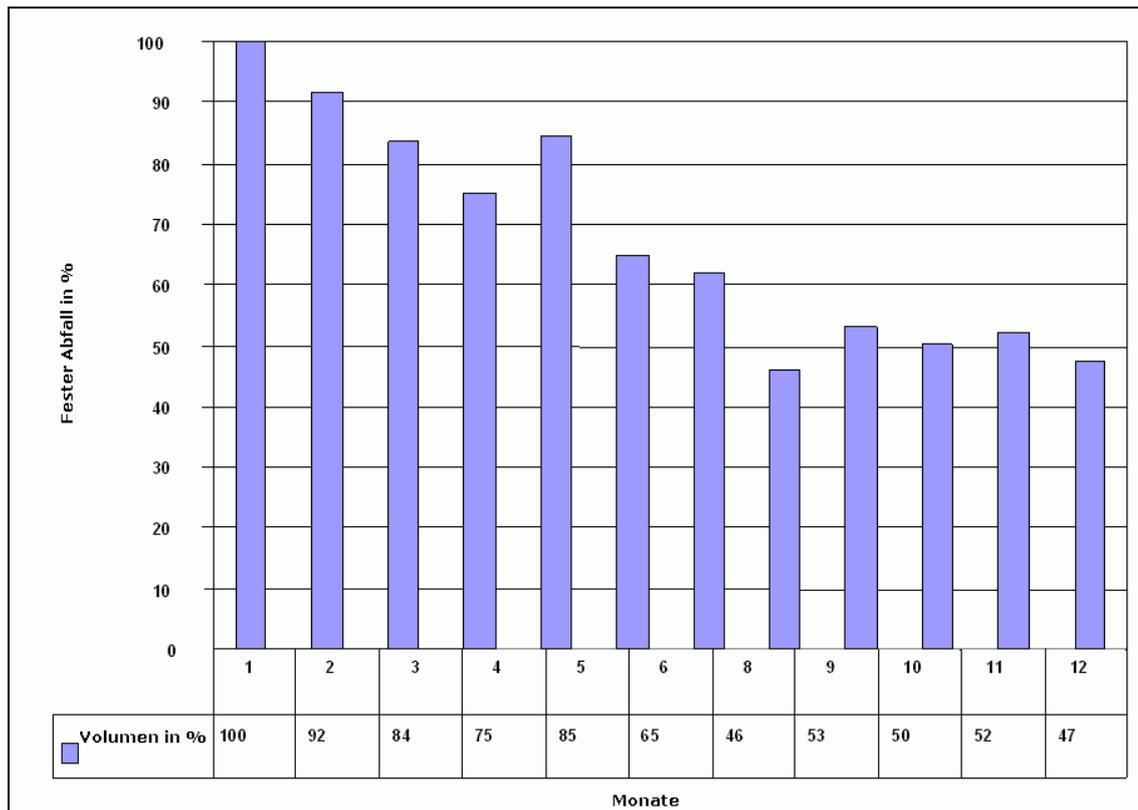


Abbildung 4.8: Abfallreduktion in der Tierfutterherstellung

In einer Beispielanlage war das Unternehmen gerade dabei, eine Anzahl wesentlicher Änderungen an bestehenden Einrichtungen vorzunehmen. Das Potenzial für erhebliche Kostenreduktionen wurde als guter Anreiz für die Geldinvestition und zur tatsächlichen Durchführung des Projekts erkannt. Für das Projekt wurde das ehrgeizige Ziel einer Verringerung der gemischten Festabfallfraktion um 50 % gesetzt. Dieses Ziel wurde erreicht.

Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

Wirtschaftlichkeit

Die Konzentration auf einige einfache Maßnahmen führte innerhalb von 8 Monaten zu erheblichen Kosteneinsparungen.

Anlässe für die Umsetzung

Erhebliche finanzielle Einsparungen durch die bessere Nutzung von Rohstoffen im Endprodukt und geringere Abfallentsorgungskosten.

Beispielanlagen

Mindestens ein Tierfutterunternehmen im Vereinigten Königreich.

Referenzliteratur

[1, CIAA, 2002]

**4.1.7.6 Trennung der anfallenden Stoffe zur Optimierung von Verbrauch, Verwertung, Rückgewinnung, Kreislaufführung und Entsorgung (sowie zur Reduzierung von Wasserverbrauch und Abwasseranfall)**

Siehe auch Abschnitt 4.3.1.

Beschreibung

Anfallende Stoffe können, ganz gleich, ob sie zur Verwendung im Produkt vorgesehen sind oder nicht, zur einfacheren und optimierten Verwendung, Verwertung, Rückgewinnung, Kreislaufführung und Entsorgung

getrennt werden. Dadurch werden auch sowohl der Verbrauch als auch die Verunreinigung von Wasser verringert. Die Durchführung kann manuell oder mechanisch erfolgen. Zu den anfallenden Stoffen können u. a. abgelehnte Rohstoffe, Schnittabfälle und nicht den Anforderungen genügende Produkte gehören.

Zum getrennten Auffangen und Aufbewahren der einzelnen Materialien können sorgfältig positionierte Spritzschutzvorrichtungen, Siebe, Klappen, Tropfschalen und Rinnen verwendet werden. Diese Vorrichtungen können in Prozess-, Abfüll-/Verpackungs- und Transferstraßen und an Arbeitsplätzen wie Tischen für das Schälen, Schneiden und Beschneiden installiert werden. Position und Konstruktion der Schalen/Rinnen und die zur Verhinderung einer Vermischung mit Wasser eingesetzten Mittel sowie der Transport der Flüssigkeiten und Feststoffe hängen vom Verfahrensschritt, dem gewünschten bzw. erforderlichen Grad der Trennung unterschiedlicher Stoffe und deren letztlichem Verwendungszweck bzw. Entsorgungsweg ab.

Beispiele für Material, das trocken aufgefangen und transportiert werden kann, sind u. a. Knochen und Fett vom Entbeinen und Beschneiden von Fleisch. Dieses Material kann für den menschlichen Verzehr vorgesehen sein oder auch nicht. Bei Materialien, die für den menschlichen Verzehr bestimmt sind, ist eine Temperaturregelung von besonderer Bedeutung. Zersetzungsprozesse lassen sich durch schnellen Transport des Materials in Kühlräume vermeiden.

Ein anderes Beispiel ist auch die Beseitigung sortierter, unbehandelter oder teilbehandelter Obst- und Gemüserückstände, Schäl- und Schnittrückstände sowie das Auffangen von Erdresten in Sedimentations- und Filterschritten anstelle der Ableitung in die Kläranlage.

In Bereichen mit potenziell starkem Abfallaufkommen können manuelle oder automatische Sammelsysteme, wie Abläufe, Pumpen oder Saugvorrichtungen, installiert werden, um die Zersetzung von Inhaltsstoffen zu verhindern und einer möglichen Nutzung, beispielsweise als Tierfutter, zuzuführen. Mit diesen Maßnahmen kann der Abstrom in die Kläranlage reduziert werden.

In der Milchwirtschaft sind Beispiele für eine Verwertung von Abfallmaterialien, die zu einer optimalen Verwertung oder Entsorgung getrennt werden, z. B. das Abtropfwasser von Joghurt und Früchten in der gesamten Molkerei; die ersten Spülgänge von Buttermilch und Restfett vom Buttern zur Verwendung in anderen Prozessen, z. B. in fettarmen Brotaufstrichen, sowie die Molke, z. B. für die Herstellung von Mizithra-Käse (siehe Abschnitt 4.7.5.1).

Beim Raffinieren von Pflanzenöl können beim Trocken des vom Lösungsmittel befreiten Schrots anfallende Stäube wieder dem Schrot zugeführt werden (siehe Abschnitt 4.7.4.10).

Manche mit Wasser verdünnten Stoffe lassen sich rückgewinnen, wenn das Wasser aufgefangen wird. So kann z. B. Kartoffelstärke aus Stärkewasser, wie unter *Betriebsdaten* beschrieben, rückgewonnen werden, und Molke lässt sich aus den Molke-Wasser-Gemischen extrahieren. Durch Einsatz von Trübungsmessgeräten (siehe Abschnitt 4.1.8.5.3) lässt sich dieser Vorgang optimieren.

Zusätzlich können Materialien durch den Einsatz von Trockenreinigungsverfahren für die Verwendung oder Entsorgung rückgewonnen werden (siehe Abschnitt 4.3.1).

#### Erreichbare Umweltvorteile

Geringerer Wasserverbrauch und weniger Eintrag von Stoffen in das Wasser, sodass weniger und geringer belastetes Abwasser entsteht. Werden Materialien effizient gesammelt, verringert sich das Volumen des für die Reinigung erforderlichen Wassers, und es wird weniger Energie zum Erwärmen des Reinigungswassers benötigt. Auch wird weniger Reinigungsmittel benötigt. Die Abwasserbelastung (z. B. BSB, CSB, Nährstoff- und Detergenzienkonzentration) pro Produktionseinheit wird verringert.

Die Trennung von Flüssigkeiten und Feststoffen, die für die Weiterverwendung oder Beseitigung vorgesehen sind, hat mehrere Vorteile. Wenn genügend getrennte Sammelsysteme bereitgestellt werden, lässt sich die Kontamination zwischen verschiedenen Nebenprodukten verringern. Durch das Trennen von Nebenprodukten können daher auch potenzielle Geruchsprobleme durch Materialien, die selbst in frischem Zustand unangenehm riechen, verringert werden, indem sie beispielsweise getrennt und unter kontrollierten Bedingungen gelagert/entfernt werden, und somit nicht eine größere Menge vermischter Nebenprodukte auf diese Weise behandelt werden muss.

Außerdem erlaubt die Trennung dank der Verhinderung von Kontaminationen die tatsächliche Verwendung einzelner verwendbarer Nebenprodukte, die im Falle einer Vermischung mit anderem, nicht verwendbarem

Material entsorgt werden müssten. So können alle Stoffe auf die jeweils am besten geeignete Weise verwertet oder entsorgt werden.

### Betriebsdaten

Die folgenden Beispiele zeigen, wie die Trennung von weniger belastetem Abwasser zu weniger Wasserverbrauch und zu weniger Abfall beitragen kann.

Bei der Fischverarbeitung kann die Verwendung von Körben oder Schalen beim Schneiden, Ausnehmen, Enthäuten und Filetieren verhindern, dass feste Abfälle auf den Boden und von dort ins Abwasser gelangen. Feinmaschige Förderbänder können zur Trennung von Abfall und Wasser an Schneide- und Ausnehmstationen eingesetzt werden, wodurch sich der CSB den Angaben zufolge um etwa 40 % senken lässt. Die aufgefangenen Feststoffe können zur Herstellung von Fischmehl verwendet werden.

Zum Auffangen von festem Abfall von Krebstieren und Muscheln sind trockene Systeme entwickelt worden. Siebe/Rechen und effiziente Systeme zur Rückgewinnung der Feststoffe verhindern, dass diese in die Kläranlage gelangen. Angaben zufolge kann der BSB<sub>5</sub> so um bis zu 35 % verringert werden.

In einer Beispielanlage, die Snacks herstellt, wurden Abwasserteilströme vor der Behandlung in der betrieblichen Behandlungsanlage abgetrennt und separat Feststoffe und Öle abgetrennt, aus denen anschließend Tierfutterkuchen hergestellt wurde. Dieses Verfahren ergab sich aus der Arbeit einer "Wasseraktionsgruppe", die aus Führungspersonal, Schichtarbeitern und dem Berater der Anlage bestand und mit Eimer und Stoppuhr den idealen Volumenstrom für jedes Gerät ermittelt hatte. Die Ergebnisse dieser Wasserprüfung zeigten, dass erhebliche Einsparungen möglich waren. Es wurden drei wesentliche Abwasserteilströme identifiziert, nämlich Kartoffelwaschwasser, kaltes Stärkewasser und ölhaltiges warmes Stärkewasser.

Bei der Obst- und Gemüseverarbeitung können feste organische Abfälle vom Schälen und Blanchieren z. B. mit Sieben, Filtern und Zentrifugen abgetrennt werden, sodass sie nicht in die Kläranlage gelangen. Diese Feststoffe können, außer wenn zum Schälen Natronlauge verwendet wurde, normalerweise als Tierfutter verwendet werden<sup>6</sup>.

In der Stärkeherstellung kann das Kartoffelwaschwasser nach der Entfernung von Sand wieder verwendet werden. Kaltes Stärkewasser kann nach Rückgewinnung der Stärke, die eine gute Qualität aufweist, wieder verwertet werden. Durch Wiederverwertung und -verwendung von Wasser ist der Wasserverbrauch Angaben zufolge um 19 % bzw. 165.000 m<sup>3</sup>/Jahr gesunken.

### Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

### Wirtschaftlichkeit

Durch die Verringerung des Wasserverbrauchs um 165.000 m<sup>3</sup>/Jahr in der Beispielanlage aus der Snack-Produktion wurden den Angaben zufolge 145.000 EUR an Wasserversorgungskosten eingespart.

### Anlass für die Umsetzung

Weniger Abfall, da rückgewonnene Stoffe verwertet werden können. Weniger Abwasserbehandlung und Abfallentsorgung und entsprechend geringere Kosten.

### Beispielanlagen

Mindestens eine Snack-Produktionsanlage im Vereinigten Königreich. Molkereien im Vereinigten Königreich und Obst- und Gemüseverarbeitungsanlagen in Belgien. Weit verbreitet in der Getränkeherstellung, z. B. bei der Weinproduktion.

### Referenzliteratur

[1, CIAA, 2002, 17, Envirowise (UK) and March Consulting Group (UK), 1998, 31, VITO, et al., 2001, 45, Envirowise (UK) and Ashact, 2001, 75, Italian contribution, 2002, 134, AWARENET, 2002]

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<sup>6</sup> Anm. d. UBA-Bearb.: Die festen Stoffe können auch anaerob vergärt, Methan erzeugt u. anschließend aerob gereinigt werden.

#### 4.1.7.7 Verwendung von Nebenprodukten, Koprodukten und Rückständen als Tierfutter

##### Beschreibung

In der Nahrungsmittelproduktion gibt es zahlreiche Beispiele für die Verwendung von Rohstoffen, teilweise verarbeiteten Lebensmitteln oder Endprodukten, die entweder ursprünglich für den menschlichen Verzehr vorgesehen waren, oder von denen der für den menschlichen Verzehr bestimmte Teil abgetrennt wurde, als Tierfutter. So können beispielsweise Lebensmittel, die den Anforderungen des Kunden nicht ganz gerecht werden oder die als Überschuss produziert wurden, als Tierfutter geeignet sein.

Die Herstellung von Tierfutter beispielsweise aus Zuckerrübenschnitzeln, Apfel- und Tomatentrester und Zitruspulpepellets mit und ohne Behandlung wird durch mehrere Faktoren eingeschränkt, wie das Verfaulen während Lagerung und Transport und das Vorhandensein unerwünschter Bestandteile wie Laugen oder Salz. Der Wassergehalt trägt maßgeblich zu den Transportkosten und in gewissem Umfang auch zur Geschwindigkeit des Fäulnisprozesses bei.

##### Erreichbare Umweltvorteile

Intensivere Nutzung von Material und geringere Abfallerzeugung. Folglich wird auch weniger Energie für die Abfallbehandlung und -entsorgung, beispielsweise in Kläranlagen, gebraucht, und es müssen weniger Abfälle aus der Nahrungsmittelproduktion in Deponien verbracht werden.

##### Medienübergreifende Effekte

Manche Materialien müssen möglicherweise bei geregelten Temperaturen gelagert werden, wenn sie nicht verbraucht werden können, bevor die Zersetzung beginnt und sie damit nicht mehr als Tierfutter geeignet sind.

##### Anwendbarkeit

Anwendbar in Anlagen der Nahrungsmittelproduktion, in denen Rohmaterial, teilweise verarbeitete Bestandteile und Produkte anfallen, die für den tierischen Verzehr geeignet und in geeignetem Zustand sind, und zwar entweder direkt oder nach weiterer Verarbeitung, und die den gesetzlichen Auflagen für Tierfutter genügen.

##### Wirtschaftlichkeit

Weniger Ankauf von Material, das nicht verwendet oder verkauft wird, und geringere Kosten für Abfallbehandlung und -entsorgung.

##### Anlass für die Umsetzung

Wirtschaftliche Nutzung von Nebenprodukten, nicht den Anforderungen genügenden Produkten und überschüssigem Material, das andernfalls als Abfall entsorgt werden müsste.

##### Beispielanlagen

In Tabelle 4.8 sind Beispiele für Quellen von Tierfutter aus Prozessen in der Produktion von Nahrungsmitteln für den menschlichen Verzehr angegeben.

| Quelle für Tierfutter  | Beispiel für Herkunft aus der Nahrungsmittelproduktion  |
|--|---|
| Knochen und Fett   | Fleischverarbeitung (unterliegt der Verordnung des Europäischen Parlaments und des Rates Nr. 1774/2002/EG [188, EC, 2002]). |
| Nicht akzeptierter Fisch   | Fischverarbeitung   |
| Stiele, Schalen und Blätter  | Obst- und Gemüseverarbeitung  |
| Obst und Gemüse, wie beispielsweise Schalen, Kerngehäuse und Schnittabfall   | Obst- und Gemüseverarbeitung  |
| Apfel- und Tomatentrester und Zitruspulpepellets, unbehandelt oder behandelt | Obst- und Gemüseverarbeitung  |
| Oliventrester  | Aus der ersten Pressung der Oliven  |
| Olivenpresskuchen  | Aus der Extraktion von Tresteröl (Oliven)   |
| Rückgewonnene freie Fettsäuren (FFS)   | Pflanzenölverarbeitung  |
| Getoastetes Schrot als Produkt der Ölsaatenverarbeitung                      | Pflanzenölverarbeitung  |
| Ölhaltiger und ausgepresstes/r Schrot/Kuchen                                 | Pflanzenölverarbeitung  |
| Phospholipide  | Pflanzenölraffination   |

| Quelle für Tierfutter   | Beispiel für Herkunft aus der Nahrungsmittelproduktion  |
|---|---|
| Verbrauchte Bleicherde (ohne Nickelkatalysatoranteile)  | Pflanzenölraffination   |
| Aus falsch befüllten Behältern rückgewonnene Produkte, z. B. durch Aufquellen oder Aufweichen (Mazerieren) der Verpackung | Molkereien, aber in allen Teilen der Nahrungsmittelproduktion anwendbar, in denen als Tierfutter geeignete Lebensmittel produziert werden |
| Ausgelaufene und verschüttete Bestandteile und teilweise oder vollständig verarbeitete Materialien                        | Molkereien, aber in allen Teilen der Nahrungsmittelproduktion anwendbar, in denen als Tierfutter geeignete Lebensmittel produziert werden |
| Spülflüssigkeit aus Joghurttrögen   | Molkereien  |
| Molke, die nicht zur Herstellung von Mizithra-Käse, Babynahrung oder anderen Produkten vorgesehen ist                     | Molkereien  |
| Milchiges Abwasser, das beim Hochfahren von Pasteurisatoren anfällt   | Molkereien  |
| Getreide, Ballaststoffe, Gluten, pflanzliches Protein und entfettetes Mehl  | Getreideverarbeitung  |
| Nasse Maische und gepresste Maische aus dem Auspressen von Rübenschnitzeln  | Zuckerextraktion aus Zuckerrüben  |
| Aus Zuckerrüben-Schwemmrinnenwasser abgetrennte pflanzliche Materie   | Zuckerextraktion aus Zuckerrüben  |
| Melasse   | Zuckerextraktion  |
| Vinassen aus der Verarbeitung von Alkohol aus Zuckerrübenmelasse  | Melassedestillation   |
| Distiller's dried grains with solubles (DDGS; etwa: Trockenschlempe)  | Maisdestillation  |
| Rückgewonnene starke Schnäpse   | Getränkeherstellung   |
| Malz  | Bier-, Lagerbier- und Whiskyproduktion (aus gekeimtem ofengetrocknetem Getreide)  |
| Spelzen und Malzschrot, die in Braugetreide und Treber gemischt werden können   | Brauereien  |
| Konzentrierte oder getrocknete Schlempe, Pot Ale, Spent Lees und Spent Wash   | Whisky-Brennereien  |
| Kühlwasser des Fermentationsgefäßes, das Rohstoffe und Rückstände des fermentierten Pflanzenmaterials enthält             | Whisky-Destillen  |
| Brauereihefe  | Fermentierung   |
| Feste organische Stoffe wie Rohmaterial, Produktrückstände und Stäube   | Trocknung   |
| Aus getrennten Abwasserströmen abgeschiedene Feststoffe und Öle   | Snack-Herstellung   |

**Tabelle 4.8: Beispiele für Quellen von Tierfutter aus der Produktion von Nahrungsmitteln für den menschlichen Verzehr**

Referenzliteratur

[1, CIAA, 2002, 10, Environment Agency of England and Wales, 2000, 13, Environment Agency of England and Wales, 2000, 31, VITO, et al., 2001, 65, Germany, 2002, 84, European Starch Association, 2001, 134, AWARENET, 2002, 141, FEDIOL, 2002, 161, Verband Deutscher Oelmuehlen, 2003]

**4.1.7.8 Trennung von Abwasserströmen zur Optimierung von Wiederverwendung und Nachbehandlung**

Beschreibung

Im Allgemeinen gibt es in einer Nahrungsmittelproduktionsanlage vier Arten von Abwasserströmen, nämlich Wasser, das direkt im Prozess eingesetzt wird, Haushalts-/Sanitärabwasser, gering verunreinigtes Abwasser und

Oberflächenwasser. Es kann ein Abwassertrennsystem entworfen werden, das diese Abwasserströme getrennt auffängt und entsprechend ihren Eigenschaften, beispielsweise ihrer Abwasserfracht, trennt.

Wo es machbar ist und die Lebensmittelsicherheit nicht beeinträchtigt wird, können die nicht kontaminierten Abwasserströme für bestimmte Prozessanwendungen wiederverwendet werden, z. B. zum Waschen, Reinigen, als Zusatzwasser, für die partielle Wiederverwendung und in Ausnahmefällen auch für den Prozess selbst. Gering belastetes Abwasser, für das keine Wiederverwendungsmöglichkeit besteht, kann unter Beachtung behördlicher Auflagen ohne Behandlung direkt abschlagen werden, ohne dass die Kläranlage zusätzlich belastet wird.

Stark belastetes Abwasser kann so abgetrennt werden, dass es entsprechend seinen Eigenschaften behandelt werden kann. Damit können Abwasserströme mit großem Volumen und geringer Abwasserlast möglicherweise entweder nach geeigneter Behandlung wiederverwertet oder ohne Behandlung direkt an die städtische Kläranlage abgegeben oder vor der Abgabe mit sonstigem behandeltem Abwasser vermischt werden.

In manchen Fällen können Stoffe aus dem Prozesswasser rückgewonnen und entweder wieder im Prozess oder für andere Verwendungen, z. B. als Tierfutter, eingesetzt werden (siehe Abschnitte 4.1.7.6 und 4.1.7.7).

#### Erreichbare Umweltvorteile

Weniger Wasserverschmutzung, da sauberes Wasser getrennt von verschmutztem Wasser gehalten wird. Dadurch weniger Energieverbrauch in der Abwasserbehandlung, da nicht das gesamte Abwasser jeder Behandlung unterzogen wird. Durch die Wiederverwendung von Wasser wird der Wasserverbrauch gesenkt; damit gehen im Allgemeinen auch die Emissionen zurück. Möglicherweise kann auch Wärme rückgewonnen werden.

#### Betriebsdaten

Es ist u. a. über folgende Möglichkeiten zur Wiederverwendung von Wasser berichtet worden:

- Verwendung von Abwasser, das im Produktionsprozess gering belastet wurde, wenn das benötigte Wasser keine Trinkwasserqualität haben muss
- in Molkereien können Kühlwasser, bei Evaporation und Trocknung anfallendes Kondensat, Permeat aus Membranabscheidungsprozessen und Reinigungswasser wiederverwendet werden
- in Obst- und Gemüseanlagen wird Wasser entweder direkt zur Vorreinigung zum Abspülen von Schmutz und Erde oder indirekt als Wärme- oder Kältequelle wiederverwendet
- partielle Wiederverwendung, bei der Abwasser für zwei oder mehr Prozesse oder Verfahren eingesetzt werden kann, bevor es abgeleitet wird, z. B. Glutenprozesswasser in Proteinabscheidungsschritten für das Waschen von Keimen und Fasern, Einweichprozesse bei der Maisstärkeverarbeitung, oder die Verwendung von Verdampferkondensat für die Zuckerextraktion aus Zuckerrüben
- Wiederverwertung innerhalb einer Vorreinigung oder bei Prozessen ohne Abwasserbehandlung
- Wiederverwertung mit Abwasserbehandlung
- während der Verdampfung anfallende Kondensate können im Prozess je nach ihrer Qualität, z. B. dem Gehalt an organischen und/oder anorganischen Stoffen und SS, wiederverwendet werden. Dampfkondensat kann als Kesselspeisewasser verwendet werden. Dadurch lässt sich eine erhebliche Menge an Wärme rückgewinnen, und außerdem können Chemikalien zur Behandlung des Kesselspeisewassers eingespart werden. Wenn Kondensat wiederverwendet wird, lässt sich dieser Vorgang optimieren, indem die Kondensatrückführung maximiert und Verluste von Entspannungsdampf aus der Kondensatrückführung vermieden werden
- Wasser, das nicht mit dem Produkt in Berührung gekommen ist, wie beispielsweise Kühlwasser aus Kühlsystemen, bestimmtes Kondensat und leicht kontaminiertes RO-Wasser, kann für die Reinigung weniger kritischer Bereiche, z. B. des Hofes, oder für die Herstellung von Reinigungslösungen verwendet werden. Angaben zufolge ist die Wiederverwendung von Kühlwasser für andere Zwecke möglicherweise nicht möglich, wenn es Biozide enthält.

#### Anwendbarkeit

In bestehenden Anlagen der Nahrungsmittelproduktion gibt es mehrere Möglichkeiten zur Wiederverwendung von gereinigtem Abwasser. Die Trennung von Abwasser in Abwasserteilströme ist in neuen und in entsprechend modifizierten bestehenden Anlagen der Nahrungsmittelproduktion möglich. In neuen Anlagen lässt sich das Abwassertrennsystem so planen, dass unterschiedliche Arten von Abwasser voneinander getrennt

werden. In bestehenden Anlagen ist das u.U. wegen hoher Kosten oder physischer bzw. baulicher Gegebenheiten der jeweiligen Anlage nicht möglich.

### Wirtschaftlichkeit

Für die Trennung von Abwasser fallen hohe Kapitalkosten an, die jedoch dadurch ausgeglichen werden können, dass die laufenden Kosten sinken, weil weniger Abwasser behandelt werden muss (vor Ort, in kommunalen Kläranlagen oder beides). Kleine, isolierte Ströme zu trennen ist möglicherweise nicht wirtschaftlich. Geringere Kosten für den Wasserverbrauch und in einigen Fällen geringerer Energieverbrauch.

### Anlass für die Umsetzung

Langfristige Absenkung der Kosten für die Abwasserbehandlung. Durch die Abtrennung von Strömen mit geringer Belastung lässt sich die Kläranlage verkleinern. Geringerer Wasser- und Energieverbrauch.

### Beispielanlagen

Wird in den Branchen Obst und Gemüse, Molkereiprodukte, Zucker, Getränke und Brauereien eingesetzt. Die Technik findet auch in mindestens einer Anlage zur Herstellung von Snacks im Vereinigten Königreich Anwendung (siehe Abschnitt 4.1.7.6).

### Referenzliteratur

[13, Environment Agency of England and Wales, 2000, 42, Nordic Council of Ministers, et al., 2001, 52, Envirowise (UK), 2000, 75, Italian contribution, 2002, 94, Environment Agency of England and Wales, 2002, 134, AWARENET, 2002]

## **4.1.7.9 Reduzierung von Heiz- und Kühlzeiten**

### Beschreibung

Zur Reduzierung des Energieverbrauchs können Heiz- und Kühlzeiten optimiert werden. Das ist auf verschiedene Weise z. B. mit einer Vorbehandlung, durch vorzeitiges Beenden eines Vorgangs, sobald der erforderliche Effekt erzielt<sup>7</sup> wurde, und durch die Auswahl von Geräten, die den erforderlichen Effekt bei minimalem Energieverbrauch erzielen, möglich.

### Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

### Betriebsdaten

Beispiele für Vorbehandlungen, durch die sich die Erwärmungsdauer verringern lässt, sind u. a. das Einweichen von Körnergemüse wie Linsen (siehe Abschnitt 2.1.4.1) und das Trocknen von Kartoffeln vor dem Frittieren bei der Herstellung von Kartoffelchips (siehe Abschnitt 2.1.4.1).

Die Beendigung des Vorgangs, sobald der erforderliche Effekt erzielt wurde, umfasst das Erhitzen von Bestandteilen nur genau für die erforderliche Dauer, z. B. beim Brotbacken oder Kochen von Würze beim Brauen (siehe Abschnitt 4.7.9.6) oder das Kühlen von Lebensmitteln auf nicht unterhalb der für die Verarbeitung oder Lagerung erforderlichen Temperatur (siehe Abschnitt 4.7.9.6).

Beispiele für das Minimieren der Erwärmungsdauer durch die Gerätewahl umfassen u. a. die direkte Erwärmung beim Backen (siehe Abschnitt 2.1.5.4) und die Verwendung von Wirbelbettrocknern (siehe Abschnitt 2.1.5.4) z. B. beim Rösten von Kaffee (siehe Abschnitt 2.1.6.3.3).

### Anwendbarkeit

Anwendbar, wo Erwärmungs- und Kühlvorgänge durchgeführt werden.

### Anlass für die Umsetzung

Geringerer Energieverbrauch und damit geringere Kosten.

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<sup>7</sup> Anm. d. Übers.: müsste im Ausgangstext "achieved" heißen

#### 4.1.7.10 Optimierung von An- und Abfahrprozessen und anderer spezieller Betriebsituationen

##### Beschreibung

Die Verfahren beim An- und Abfahren von Anlagen und andere spezielle Betriebsituationen lassen sich optimieren. So können zum Beispiel Abgase aus Spülentlüftungen oder das Vorheizen von Geräten minimiert werden, wenn diese so wenig wie möglich an- und abgefahren werden. Die Emissionsspitzen, die mit dem An- bzw. Abfahren verbunden sind, lassen sich so vermeiden, wodurch auch die Emissionen pro Tonne Ausgangsmaterial sinken. Dasselbe gilt für den Betrieb von Emissionsminderungsanlagen.

##### Erreichbare Umweltvorteile

Je nach Anwendung lassen sich Verringerungen von Energieverbrauch, Abfallaufkommen und Emissionen in Luft und Wasser erzielen.

##### Betriebsdaten

Bei der Behandlung von Abluft z. B. werden thermische Nachverbrennungsanlagen für Abgas erst dann effektiv betrieben, wenn sie die Verbrennungstemperaturen der Schadstoffe erreicht haben, die sie zerstören sollen. Das bedeutet, dass sie hochgefahren werden müssen, bevor sie eigentlich benötigt werden (siehe Abschnitte 4.4.3.11.1 und 4.4.3.11.3).

##### Anlass für die Umsetzung

Geringerer Verbrauch und geringere Emissionen.

##### Referenzliteratur

[65, Germany, 2002]

#### 4.1.7.11 Gute handwerkliche Praxis

##### Beschreibung

Wird ein System entwickelt und auch betrieben, das für den sauberen und ordentlichen Betrieb der Anlage sorgt, so lässt sich auch dadurch die Umweltbilanz insgesamt verbessern. Wenn Material und Geräte sich am vorgesehenen Ort befinden, ist es einfacher, sicherzustellen, dass Haltbarkeitsdaten beachtet werden und weniger Abfall entsteht. Auch ist die Anlage dann leichter zu reinigen, wodurch sich das Risiko eines Befalls durch Insekten, Nagetiere und Vögel verringert. Verschüttungen und Leckagen lassen sich aktiv minimieren, und verschüttetes Material kann sofort trocken aufgenommen werden.

##### Erreichbare Umweltvorteile

Weniger Abfallentstehung, weniger Verunreinigung des Abwassers durch Nassreinigungen, weniger Geruchsbildung und -emission und geringeres Risiko des Befalls durch Insekten, Nagetiere und Vögel.

##### Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

##### Wirtschaftlichkeit

Vermeidet Ausgaben für Geruchsminderung, Abfallentsorgung und Abwasserbehandlung.

##### Anlass für die Umsetzung

Weniger Abfallentstehung und größere Sicherheit (Vermeidung von Betriebsstörungen durch Ausrutschen und Stolpern).

#### 4.1.7.12 Geordnete Fahrzeugbewegungen am Standort

##### Beschreibung

Durch geregelte Zeiten für die Zufahrt zur und die Ausfahrt aus der Anlage durch Fahrzeuge sowie durch die Festlegung von Orten und Zeiten, an bzw. zu denen sich Fahrzeuge auf dem Anlagengelände bewegen, können die vom Standort ausgehenden Lärmemissionen zu kritischen Zeiten, z. B. nachts, wenn Anrainer in Wohngebieten normalerweise schlafen wollen, verringert werden.

Durch die Wahl ruhiger Fahrzeuge und deren angemessene Wartung sowie durch Straßenbeläge mit geringen Geräuschübertragungseigenschaften lässt sich diese Praxis weiter optimieren.

Erreichbare Umweltvorteile

Weniger Lärmemissionen in der Nacht.

Medienübergreifende Effekte

Mehr Lärm- und Fahrzeugemissionen am Tag.

Betriebsdaten

Bei manchen Prozessen in der Nahrungsmittelproduktion, die rund um die Uhr laufen, kann es wegen des Bedarfs an frisch angelieferten, zur sofortigen Verarbeitung bestimmten Materialien möglich sein, dass sich die Anlieferung nicht nur auf den Tag beschränken lässt. Dies gilt z. B. für die Obst- und Gemüseverarbeitung, wenn die Ernte und Verarbeitung von beispielsweise Tomaten oder Erbsen rund um die Uhr erfolgt, damit Reife und Geschmack gewährleistet sind.

Es kann schwierig sein, die Ankunfts- und Abfahrtszeiten von Schichtarbeitern so einzuschränken, dass Zeiten vermieden werden, in denen es zu einer Lärmbelästigung für die Anwohner kommt.

In der Nachbarschaft einer großen Beispiel-Brauerei, die an Werktagen rund um die Uhr in Betrieb ist, wurden die Lärmpegel gemessen. Die der Brauerei zugeschriebenen Lärmpegel wurden an den nächstgelegenen, als solche identifizierten Immissionsstellen gemessen. Außerdem wurden an den nächstgelegenen Immissionsnachweisstellen Berechnungen der Lärmpegel durchgeführt, die durch den Verkehrsfluss zur und von der Brauerei verursacht werden, wie beispielsweise durch Anlieferung von Rohmaterial wie Malz und den Abtransport von Produkten, Nebenprodukten und Abfall, in Flaschen und Dosen abgefülltes Bier, Hefe und Brauereirückstände, sowie den innerbetrieblichen Verkehr z. B. durch Gabelstapler und durch Autos verursachten Lärms. Ein- und ausfahrender Verkehr sind bei der Brauerei auf den Tag beschränkt.

Als Immissionsnachweisstellen wurden sechs Landparzellen bestimmt. Mit Ausnahme einer Fläche, auf der Lager- und Werkstattgebäude standen, waren diese Parzellen unbebaut.

Die Immissionsmessungen, die der Brauerei zugeschrieben wurden, für die nächstgelegenen Immissionsnachweisstellen sind in Tabelle 4.9 angegeben. Lärmquellen waren Ventilatoren, Kompressoren und kurze Entspannungsgeräusche von Ventilen.

| Messstelle*   | L <sub>AFm</sub><br>(dB(A)) | L <sub>AF95</sub><br>(dB(A)) | Lärmquelle   |
|---|-----------------------------|------------------------------|--|
| 1 (100 m Abstand)   | 43,3                        | 42,0                         | Gebläse der Abwasseranlage                             |
| 2 (110 m Abstand)   | 48,0                        | 46,5                         | Gebläse des CIP-Systems,<br>Dachgebläse                |
| 3 (75 m Abstand)  | 49,7                        | 48,0                         | Gebläse des CIP-Systems,<br>Dachgebläse                |
| 4 (120 m Abstand)   | 48,6                        | 46,0                         | Gebläse des CIP-Systems,<br>Druckluftherzeugungsanlage |
| 5 (110 m Abstand)   | 45,8                        | 44,5                         | Druckluftherzeugungsanlage                             |
| 6 (110 m Abstand)   | 46,9                        | 45,5                         | Druckluftherzeugungsanlage                             |
| L <sub>AFm</sub> = maximaler am Lärmmesser gemessener/abgelesener Lärmpegel während der betrachteten Zeit |                             |                              |  |
| L <sub>AF95</sub> = gemessener Lärmpegel in dB(A), während 95 % der betrachteten Zeit überschritten       |                             |                              |  |
| *Der Messzeitraum betrug 1,5 bis 10 Minuten. Die Werte stellen Mittelwerte aus drei Messungen dar.        |                             |                              |  |

**Tabelle 4.9: Lärmmessungen (Mittelwerte dreier unabhängiger Messungen) aus einer deutschen Brauerei**

Die Messwerte in Tabelle 4.10 geben die für den Tages- und Nachtbetrieb berechneten Lärmemissionen aus internem Anlagenverkehr und Lieferantenverkehr an.

| Mess-<br>stelle | Teil-<br>beurteilungs-<br>pegel – nachts<br><br>(dB(A)) | Teil-<br>beurteilungs-<br>pegel – tags<br><br>(dB(A)) | Beurteilungs-<br>pegel<br><br>(dB(A)) |        |
|-----------------|---|---|---------------------------------------|--------|
|                 |   |   | tags                                  | nachts |
| 1               | 43,5  | 52,9  | 53,7                                  | 46,4   |
| 2               | 41,2  | 51,0  | 53,7                                  | 49,0   |
| 3               | 30,9  | 44,3  | 52,8                                  | 49,7   |
| 4               | 24,4  | 37,3  | 51,2                                  | 48,6   |
| 5               | 31,7  | 41,7  | 49,1                                  | 46,0   |
| 6               | 35,9  | 44,9  | 50,1                                  | 47,2   |

**Tabelle 4.10: Berechnete Teilbeurteilungspegel für Materialtransport- und Umschlagsprozesse**

Bei der Berechnung der Tagesbeurteilungspegel wurden die in Tabelle 4.9 angegebenen Werte durch einen Zuschlag von 2,4 dB(A) für Ruheperioden (06:00 Uhr bis 07:00 Uhr und 20:00 Uhr bis 22:00 Uhr) angehoben. Die gemessenen Werte an allen sechs Messstellen lagen deutlich unter dem örtlichen Immissionsrichtwert für den Tag und entsprachen auch dem Immissionsrichtwert für die Nacht.

Durch die Konzentration der Fahrzeugbewegungen auf den Tag können sich unterschiedliche Auswirkungen auf die Arbeitssicherheit ergeben. Am Tag mögen zwar die Sichtverhältnisse besser sein, aber dann halten sich vielleicht auch mehr Personen in der Anlage auf. Zusammen mit der zusätzlichen Konzentration von Fahrzeugen werden daher die Organisation der Fahrzeugbewegungen und die Trennung von Fahrzeugen und Menschen besonders wichtig.

Durch eine Einschränkung der Zeiten für den Zuliefer- und Abtransportverkehr kann es außerhalb einer jeden Anlage zu Verkehrsstaus kommen.

#### Anwendbarkeit

In praktisch allen Anlagen der Nahrungsmittelproduktion anwendbar.

#### Anlass für die Umsetzung

Gute Beziehungen zu Anrainern und Vermeidung von Beschwerden über Lärmpegel außerhalb der Anlage.

#### Beispielanlagen

Mindestens eine Brauerei in Deutschland.

#### Referenzliteratur

[65, Germany, 2002]

### **4.1.8 Techniken für die Prozesssteuerung**

Zu den Vorteilen einer verbesserten Prozesssteuerung gehören die Steigerung des verkäuflichen Anteils an der Produktion, eine bessere Qualität und weniger Abfall.

Durch die Verbesserung der eingesetzten Stoffe in der Prozesssteuerung, des Prozessverlaufs, des Umgangs mit den Einsatzstoffen, der Lagerung der Stoffe und der Reduzierung des Abwasseranfalls lassen sich die Abfallmengen reduzieren.

Um die Prozesssteuerung verbessern zu können, muss zunächst bestimmt werden, in welchen Prozessstufen Abfall entsteht, wodurch dieser Abfall bedingt ist und welche Verbesserungen gemacht werden können, um die Abfallmenge zu reduzieren. So können durch Überlaufen bedingte Verluste beispielsweise durch Installation eines Niveauewächters, eines Schwimmerventils oder eines Durchflussmessers verhindert werden. Die erforderliche Wartungs-, Reinigungs- und Kalibrierhäufigkeit solcher Geräte hängt von ihrer Konzeption und der Einsatzhäufigkeit bzw. den Einsatzbedingungen ab.

Es ist unbedingt erforderlich, dass Geräte für die Prozessüberwachung und -steuerung so geplant, installiert und betrieben werden, dass sie die Hygienebedingungen des Produktionsprozesses nicht beeinträchtigen und nicht

selbst zu Produktverlusten und Abfallentstehung führen. Weitere Informationen zur Überwachung finden sich im Referenzdokument über die allgemeinen Überwachungsgrundsätze [96, EC, 2003].

### 4.1.8.1 Temperaturregelung durch spezielle Messungen und Korrekturen

#### Beschreibung

Abfälle aus Rohmaterial und Abwasser lassen sich durch eine Temperaturregelung beispielsweise in Lager- und Prozessbehältern sowie Transportleitungen, verringern. Zu den möglichen Vorteilen dieser Maßnahme zählen weniger Materialverfall, insgesamt höhere Produktqualität und weniger biologische Kontamination. Der Einsatz von Temperaturfühler lässt sich in manchen Fällen optimieren, indem sie doppelt genutzt werden, z. B. zur Temperaturüberwachung von Produkten und bei der Reinigung.

#### Erreichbare Umweltvorteile

Geringerer Energieverbrauch und weniger Abfall; möglicherweise auch Senkung des Wasserverbrauchs, wenn Wasser oder Dampf zu Heizzwecken verwendet werden.

#### Betriebsdaten

Für Molkereien wird angegeben, dass die Milchtemperatur während der Wärmebehandlung durch die Steuerung des Dampf- oder Heißwasserstroms gehalten werden kann.

In der Konditoreiwarenherstellung können Temperaturfühler dazu verwendet werden, den Temperaturabfall während des Produkttransfers zu minimieren und so den Verderb der Produkte zu verringern.

Bei der Fleischverarbeitung kann die Temperatur von Auftaubädern für gefrorenes Fleisch durch die Regulierung des Wasserstroms aufrechterhalten werden.

In einer Beispielanlage für Fleischverarbeitung konnten die Wasserversorgungskosten durch den Einbau von Thermoelementen für die Temperaturregelung um bis zu 10 % gesenkt werden. Thermoelemente an Wasserzufuhr und -auslass eines Kühl- und Waschsystems liefern Werte an ein automatisches Regulierventil, das die Flussrate optimiert. Durch das Regulierventil wurden Wasser- und Energieverbrauch und Abwassermenge wesentlich gesenkt und gleichzeitig eine Flussrate beibehalten, die den Hygieneanforderungen des Prozesses genügt.

Ein Unternehmen, das zur Alkoholproduktion Melasse fermentiert, installierte eine verbesserte Temperaturregelung in einem Fermentationsgefäß, in dem die erforderliche Temperatur regelmäßig um 5 °C überschritten wurde. Das Ergebnis war eine erhöhte Ausbeute und eine Abfallreduktion um 15 %.

#### Anwendbarkeit

Anwendbar in Anlagen, in denen Wärmeprozesse eingesetzt werden und/oder Material bei kritischen Temperaturen oder innerhalb kritischer Temperaturbereiche gelagert oder umgefüllt wird.

#### Wirtschaftlichkeit

In dem Beispiel, in dem Thermoelemente eingesetzt wurden, gab das Unternehmen jährliche Einsparungen in Höhe von 130.000 GBP bei einer Anfangsinvestition von 3.000 GBP an, was einem Amortisationszeitraum von 12 Wochen entspricht (im Jahr 2000). Die Einsparungen lassen sich durch höhere Produktausbeuten und geringere Abfallentstehung erzielen.

#### Anlass für die Umsetzung

Minimierung des Produktverfalls, erhöhte Produktausbeuten und geringerer Wasserverbrauch.

#### Beispielanlagen

Wird in Molkereien, der Konditoreiwarenherstellung, mindestens einer Fleischverarbeitungsanlage im Vereinigten Königreich und mindestens einer Melassefermentationsanlage im Vereinigten Königreich eingesetzt.

#### Referenzliteratur

[18, Envirowise (UK) & Entec UK Ltd, 1999]

#### 4.1.8.2 Steuerung der Durchflussmenge oder Füllstandshöhe durch eigene Druckmessungen

##### Beschreibung

Druck oder Vakuum lassen sich bei verschiedenen Verfahren, z. B. beim Filtrieren, Trocknen, Fermentieren und Autoklavieren einsetzen.

Andere Parameter wie Durchfluss und Füllstandshöhe können normalerweise durch Druckregelung mit Drucksensoren indirekt gesteuert werden. Verwendung von Druckmesssonden in Transferstraßen zur Regulierung von Pumpdrehzahl, Druck und Strömungsgeschwindigkeit sowie zur Minimierung von Materialverlusten durch Scher- oder Reibungskräfte. Verwendung eines Differenzialdrucksystems zur Überwachung von Füllstandshöhen in Lager- oder Reaktionsbecken zur Minimierung von Überlaufverlusten oder Produktionsausfallzeiten wegen unzureichenden Lagerbestands. Verwendung eines Differenzdrucksystems zur Überwachung von Druckabfällen bei Filtern, zur Steuerung von Reinigungszyklen und zur Optimierung des Betriebs, wodurch Verluste minimiert werden.

Die in Anlagen der Nahrungsmittelproduktion verwendeten Drucksensoren müssen im Allgemeinen abgedichtet sein und über Oberflächen verfügen, die eigens für hygienische Anwendungen konstruiert sind.

##### Erreichbare Umweltvorteile

Reduzierung von Abfällen.

##### Betriebsdaten

In einer Beispielanlage in der Fruchtsaftproduktion wird das Produkt vor dem Abfüllen in Flaschen filtriert, um Fruchtfleischreste zu entfernen. Es wurde die regelmäßige Reinigung des Filters mittels einer durch einen Zeitgeber gesteuerten Spülleitung eingeführt. Das Unternehmen erkannte, dass dadurch die Filter öfter als nötig gereinigt wurden. An drei Filtriereinrichtungen wurden Druckdifferenzsensoren installiert, die jetzt den Reinigungszyklus auslösen. Das Signal erfolgt, wenn ein voreingestellter Druck am Filter erreicht wird. Der Wasserverbrauch für die Filterreinigung sank um 30 %.

In einer Beispielmolkerei wird die Druckmessung zur Überwachung und Regelung mittels Pumpensteuerung von Fließgeschwindigkeiten in Rohrleitungen eingesetzt, um Reibungsschäden am Produkt zu vermeiden.

In einer Beispielbrauerei wird die Druckmessung zur Überwachung und Regelung des Wasserdrucks für das Sprühwasser für das Malz in den Maischefiltern, also bei der Sprühreinigung, verwendet.

##### Anwendbarkeit

Anwendbar in Anlagen, in den Flüssigkeiten strömen oder gepumpt werden, wie im Getränke- und Milchsektor.

##### Wirtschaftlichkeit

In einer Fruchtsaftanlage, über die berichtet wird, führte der geringere Wasserverbrauch für die Filterreinigung zu einer Einsparung von 8.000 GBP/Jahr für Wasserverbrauch und Abwasserbehandlung. Der Umbau kostete 6.000 GBP, sodass der Amortisationszeitraum 9 Monate betrug.

##### Beispielanlagen

Eine Fruchtsaftanlage, eine Molkerei und eine Brauerei im Vereinigten Königreich.

##### Referenzliteratur

[18, Envirowise (UK) & Entec UK Ltd, 1999]

#### 4.1.8.3 Füllstandsmessung

##### Beschreibung

Die zwei Hauptkategorien von Füllstandssensoren sind Sensoren zur Grenzwertfassung und Sensoren für die kontinuierliche Messung. Grenzwertfassungssensoren geben an, ob an einem bestimmten Punkt in einem Gefäß (normalerweise ein Maximum bzw. Minimum) Flüssigkeit vorhanden ist. Die meisten dieser Anwendungen sind verbunden mit einer Sichtanzeige, einem optischen oder akustischen Warnsignal oder der Ein-/Aus-Steuerung von Zu- und Abflüssen zum bzw. aus dem Gefäß. Sensoren für die kontinuierliche Messung ermöglichen die laufende Überwachung des tatsächlichen Füllstandes mit verschiedenen Steuerungsmöglichkeiten, z. B. zur Beschleunigung oder Verlangsamung von Pumpvorgängen.

### Erreichbare Umweltvorteile

Geringerer Verbrauch an Reinigungsmaterial und Wasser; geringere Abwassermenge und geringeres Kontaminationsrisiko für Boden, Oberflächen- und Grundwasser.

### Betriebsdaten

In einer Beispielbrauerei wird ein kapazitiver Niveauschalter verwendet, um die Grenzfläche zwischen Hefe und Bier zu ermitteln. Das Bier wurde dann für die Lagerung abgeführt. Die Hefe kann rückgewonnen und als Tierfutter verwendet werden (siehe Abschnitt 4.7.9.3).

Bei der Bierherstellung führt jedes Prozent an Würze, das ins Abwasser gelangt, zu einer Erhöhung des CSB im Abwasser um etwa 5 %. Durch die Verwendung von Füllstandssensoren lässt sich diese Verunreinigung verhindern, da das Überfüllen von Prozessgefäßen mit sehr hohem CSB vermieden wird.

In einem großen, als Beispiel genannten Gemüseverarbeitungsunternehmen wurden durch den Einbau von Füllstandsreglern an den Wasservorratstanks für das Schwemmsystem, mit dem das Gemüse transportiert wird, Einsparungen bei Wasserkosten, Abwasserentsorgungskosten und Arbeitsstunden erzielt. Zuvor wurde die Wasserzufuhr manuell durch den Bediener geregelt, was zu übermäßigem Überlaufen aus den Becken führte, wenn der Bediener anderweitig beschäftigt war. Ein einfaches Schwimmerventil stellte eine kostengünstige Lösung dar. Das Ventil regelt jetzt die Wasserzufuhr zu den Becken und der Bediener kann an anderer Stelle arbeiten.

### Anwendbarkeit

In der Nahrungsmittelproduktion an vielen Stellen anwendbar, z. B. wo Flüssigkeiten in Becken oder Gefäßen gelagert oder verarbeitet werden, und zwar sowohl bei Herstellungs- als auch Reinigungsprozessen. Tabelle 4.11 zeigt einige Beispiele für den Einsatz von Füllstandssensoren zur Verringerung von Materialabfall und Abwassermenge.

| <b>Anlage</b>                              | <b>Grund für die Regulierung</b>   |
|--|--|
| Lager- oder Reaktionsbecken                | Verhinderung von Überläufen und Material- oder Wasserverlusten   |
| Lagerbehälter                              | Datengewinnung für die Lagerhaltung. Minimierung der Abfälle in Form von abgelaufenem Lagergut und von Produktionsausfällen durch das Fehlen von Material. |
| Behälter mit automatischer Umfüllsteuerung | Minimierung des Abfalls durch Umfüllverluste und ungenaue Chargenrezeptierung  |
| Flüssige Lebensmittel                      | Überwachung des Füllstands in Lagerbehältern zur Vermeidung von Überläufen und Verlusten in das Abwasser   |
| CIP/Sterilisation an Ort und Stelle        | Als Niveauschalter bei der Behälterreinigung zur Optimierung der verwendeten Mengen von Wasser und Reinigungsmitteln sowie als Überlaufschutz              |

**Tabelle 4.11: Beispiele für die Verwendung von Füllstandssensoren in der Nahrungsmittelverarbeitung**

### Wirtschaftlichkeit

In der Beispielbrauerei betragen die Kosten für die Umbauten 9.500 GBP (1999), aber die dadurch bewirkten Rückgänge an Bierverlusten und Abwasserbehandlungskosten in Höhe von 800.000 GBP/Jahr bedeuteten eine Amortisationszeit von 5 Tagen.

Das Gemüseverarbeitungsunternehmen aus dem Beispiel sparte durch geringere Wasserkosten, Abwassergebühren und Arbeitszeiten jährlich mehr als 15.000 GBP ein. Die Amortisationsdauer betrug ein paar Monate.

### Anlass für die Umsetzung

Teure Produktverluste.

### Beispielanlagen

In der Nahrungsmittelproduktion in vielen Bereichen anwendbar.

Referenzliteratur

[1, CIAA, 2002, 11, Environment Agency of England and Wales, 2000, 13, Environment Agency of England and Wales, 2000, 18, Envirowise (UK) & Entec UK Ltd, 1999]

**4.1.8.4 Durchflussmessung und -regulierung**Beschreibung

Techniken zur Durchflussmessung und -regulierung können Materialverluste und Abwasserentstehung in der Nahrungsmittelverarbeitung verringern. Mittels Durchflussmessung und -steuerung in Transferstraßen wird die genaue Zugabe von Material zu Lager- und Prozessbehältern und in Verpackungsvorgängen ermöglicht; dadurch kann übermäßiger Materialverbrauch und die Erzeugung von nicht den Anforderungen genügenden Produkten reduziert werden.

Durchflussmesser ohne in den Messraum ragendes Messelement, z. B. elektromagnetische Messvorrichtungen, sind für die hygienische Anwendung besonders geeignet. Zwecks Reduzierung der Kontamination müssen Durchflussmesser robust sein und leicht zu reinigen. In Prozessen, in denen Flüssigkeiten sich bei niedrigen Temperaturen verfestigen können, ist eventuell eine Begleitheizung erforderlich, um sicherzustellen, dass die Flüssigkeit sich nicht in oder bei den entsprechenden Geräten verfestigt. Es gibt verschiedene Arten von Durchflussmessern, z. B. Rotameter, Verdrängungsmesser, elektromagnetische Durchflussmesser, Ultraschall-durchflussmesser und Wirbelzähler. Für jeden Typ gelten besondere Installationsanforderungen, damit eine korrekte Messung gewährleistet ist.

In CIP-Systemen kann der Wasserverbrauch über die Durchflussmessung gesteuert und optimiert und so die anfallende Abwassermenge minimiert werden.

Die Kontrolle von Reinigungs- und Spülgrenzflächen ist besonders wichtig, da diese zu erheblichen Verlusten beitragen können. Durch die Verwendung von Durchfluss- oder Leitfähigkeitsmessern können beispielsweise Wasser-/Milchgrenzflächen genau erkannt und somit die an das Abwasser verlorene Menge an Rohmilch minimiert werden. Auch Molchsysteme können zur Wartung solcher Grenzflächen verwendet werden (siehe Abschnitt 4.3.3).

Erreichbare Umweltvorteile

Weniger Verluste von Material, Produkten und Wasser und geringeres Abwasseraufkommen.

Betriebsdaten

Bei der Verarbeitung von Hackfleisch kann der Wasserstrom zu Wurstfüllmaschinen und ähnlichen Geräten minimiert werden. Die Wasserzufuhr wird automatisch unterbrochen, wenn das Gerät in Arbeitspausen oder Produktionsunterbrechungen nicht verwendet wird.

In einer Beispielmolkerei, in der wöchentlich 3.000 m<sup>3</sup> Rohmilch verarbeitet werden, wurden durch die Optimierung der Wasser-/Milchgrenzfläche mit Durchflussmessern und Leitfähigkeitssonden 0,2 % Milchabfall eingespart. Der CSB im Endabwasser der Anlage wurde von 3.100 mg/l auf 2.500 mg/l gesenkt.

In einem Unternehmen, das Gemüse verarbeitet, wurden manuelle Mengensteuerventile am Wasserzufluss zum Transportsystem installiert. Dadurch konnten die Bediener Feineinstellungen des Wasserstroms vornehmen. Außerdem konnte eine bestimmte Ventileinstellung und Durchflussrate leicht wieder eingestellt werden.

Ein Konditoreiwarenhersteller stellte fest, dass die Schokoladenüberzüge seiner Produkte erhebliche Gewichtsschwankungen aufwiesen. Es wurde eine Reihe von Maßnahmen ergriffen, um die Schokoladenzugabe besser zu steuern. Dazu zählte auch die Installation eines elektromagnetischen Durchflussmessers und eines Regelventils zur genauen Steuerung der Schokoladenzufuhr. Der Verbrauch wurde um 10 Tonnen/Jahr gesenkt.

Ein Fertigerichtehersteller installierte ein Verdrängungsmessgerät, um den Wasserverbrauch in seiner Geräteeinigungsanlage genauer zu untersuchen. Nach mehreren Wochen der Überwachung stellte sich heraus, dass der Wasserverbrauch stark schwankte, und zwar ohne Zusammenhang zur jeweiligen Produktionsmenge. Nach Gesprächen mit den Arbeitskräften im betroffenen Bereich wurden bessere Reinigungsverfahren eingeführt. Das Resultat war eine sofortige Absenkung des Wasserverbrauchs um 80 m<sup>3</sup>/Woche.

Angaben zufolge kann in der Getränkeherstellung der Flüssigkeitszufluss in den Behältern gemessen (überwacht) werden, anstatt sie bis zur Kapazitätsgrenze zu füllen.

### Anwendbarkeit

In der Nahrungsmittelproduktion in vielen Bereichen anwendbar. Tabelle 4.12 enthält Beispiele für die allgemeine Anwendbarkeit der Durchflussmessung und -regelung.

| Geräte            | Zustand/Aktivität                                  | Grund für die Regulierung  |
|-------------------|--|--|
| Transferstraßen   | Genauere Zugabe von Material zu Reaktionsbehältern | Minimierung übermäßigen Materialverbrauchs und der Erzeugung nicht den Anforderungen entsprechender Produkte |
| Dampfzufuhr       | Aufrechterhaltung der richtigen Betriebstemperatur | Minimierung des durch zu sehr oder zu wenig erwärmte Materialien und Produkte entstehenden Abfalls           |
| Reinigungssysteme | Wasserverbrauch                                    | Optimierung des Verbrauchs und Minimierung der Abwasserentstehung  |

**Tabelle 4.12: Beispiele für den Einsatz von Durchflussregulierung in der Nahrungsmittelproduktion**

Einige typische Anwendungen für die Durchflussmessung sind in Tabelle 4.13 aufgeführt.

| Produkt/Aktivität     | Anwendung   |
|-----------------------|---|
| Alkoholfreie Getränke | Durchflussmessung und Wirkungskontrolle für die Zugabe von Rohstoffen   |
| Schüttgut             | Beispiel: Regulierung des Zuflusses von Kartoffelchips in eine Würztrommel zur Gewährleistung der richtigen Würzung |
| Milchpulver           | Durchflussmessung für die genaue und dem Rezept entsprechende Chargenzugabe der Zutaten in den Prozess              |
| CIP                   | Durchflussmessung zur Gewährleistung der Abgabe eines bestimmten Wasservolumens für jeden Reinigungsschritt         |

**Tabelle 4.13: Typische Anwendungen der Durchflussmessung im Nahrungsmittelsektor**

### Wirtschaftlichkeit

In der Beispielmolkerei betragen die Einsparungen für Rohmilch und Abwasser jährlich 88.640 GBP.

Bei der oben erwähnten Gemüseverarbeitung sparte das Unternehmen bei auf optimalen Durchfluss eingestellten Ventilen jährlich etwa 18.000 GBP an Wasser- und Abwasserkosten. Die Amortisationsdauer betrug 3 Monate.

Im genannten Konditoreiwarenunternehmen kostete die Umsetzung der Veränderungen 7.500 GBP, aber der Rückgang im Schokoladenverbrauch entsprach 15.000 GBP/Jahr, was einen Amortisationszeitraum von 6 Monaten bedeutet.

Die verbesserte Wassernutzung im Fertigerichteunternehmen führte zu einer Einsparung von 3.000 GBP/Jahr an Wasser- und Abwasserkosten, was einer Amortisationsdauer von 10 Wochen für die 600 GBP entspricht, die für die Installation des Messgeräts aufgewendet wurden.

### Anlass für die Umsetzung

Weniger Material- und Wasserverschwendung und entsprechende Kosteneinsparungen. Weniger gelieferte Überschussmengen und dadurch Kosteneinsparungen.

### Beispielanlagen

Durchflussmessung und -regelung ist in der Nahrungsmittelproduktion weit verbreitet.

### Referenzliteratur

[11, Environment Agency of England and Wales, 2000, 18, Envirowise (UK) & Entec UK Ltd, 1999, 41, Nordic Council of Ministers, 2001]

### 4.1.8.5 Analytische Messungen

Zur Minimierung von Materialverlusten und zur Qualitätsprüfung von Material werden bei einer Reihe von Flüssigkeiten während des Prozesses üblicherweise pH-Wert, Leitfähigkeit und Trübung überprüft.

#### 4.1.8.5.1 pH-Messung

##### Beschreibung

pH-Sonden messen den Säuregrad oder die Basizität einer Flüssigkeit. Der pH-Wert ist in vielen Bereichen wichtig, z. B. für die Kontrolle der Milchqualität, die Überwachung von Rahm- und Käseerzeugung, bei Fermentationsprozessen, in der Produktion von Säuglingsnahrung und in der Wasseraufbereitung und Abwasserbehandlung.

Die Sonden können fest in eine Prozessstraße integriert sein oder manuell in Becken und Lagergefäße getaucht werden. Es sind verschiedene Geräte erhältlich. Sie reichen von einfachen Sonden und Transmittern bis hin zu automatischen Sonden, die den Bediener auf Gerätefehler aufmerksam machen und ohne Ausbau gewartet und kalibriert werden können.

##### Erreichbare Umweltvorteile

Geringerer Verbrauch an Säuren und Basen und entsprechend weniger Abwasseraufkommen. Weniger Verluste von Prozessmaterial durch unerwünschtes Vermischen während Verarbeitung und Reinigung.

##### Betriebsdaten

Zur Vermeidung fehlerhafter Ergebnisse sollte die Geschwindigkeit der Flüssigkeit nicht mehr als 2 m/s betragen. Die Elektrode ist grundsätzlich zu befeuchten, um einen Funktionsverlust zu vermeiden.

Ein Konditoreiwarenunternehmen verwendet eine pH-Sonde, um die Laugendosierung zu einem Abwasserstrom zu steuern. Die pH-Steuerung gewährleistet nicht nur die Einhaltung der rechtlichen Einleitungsbedingungen für das Abwasser, sondern minimiert auch das Risiko teurer Korrosionsschäden im Abwassersystem durch Säure- oder Baseneinwirkung.

##### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion, in denen saure oder basische Substanzen den Prozess-, Reinigungs- oder Abwasserströmen hinzugefügt werden. Beispiele für den Einsatz von pH-Messungen in der Nahrungsmittelproduktion sind in Tabelle 4.14 aufgeführt. Typische Anwendungen von pH-Messungen in der Nahrungsmittelproduktion sind in Tabelle 4.15 aufgeführt.

| Aktivität  | Grund für Regulierung  |
|--|--|
| Regulierung der Zugabe von Säuren oder Laugen in Reaktionsbehälter                                   | Minimierung von Verlusten durch Überdosierung und Erzeugung nicht anforderungsgerechter Produkte |
| Überwachung von Abwasserströmen, die vor der Abgabe zum Mischen und Neutralisieren eingesetzt werden | Minimierung des Einsatzes frischer Natronlauge oder Säuren für die Abwasserbehandlung            |

Tabelle 4.14: Beispiele für den Einsatz von pH-Messungen in der Nahrungsmittelproduktion

| Sektor/Aktivität      | Anwendung   |
|-----------------------|---|
| Molkerei              | pH-Untersuchung der angelieferten Milch zur Vermeidung von Verlusten durch Vermischen ungeeigneter Milch mit anderen Rohstoffen |
| Marmeladenherstellung | pH-Messung zur Identifizierung des richtigen Gelpunkts  |

Tabelle 4.15: Typische Anwendungen der pH-Messung in der Nahrungsmittelproduktion

##### Anlass für die Umsetzung

Weniger Verbrauch an Säuren und Laugen, z. B. bei der CIP, und weniger Abfallentstehung.

### Beispielanlagen

Molkereiwesen, Marmeladenherstellung, Abwasserbehandlung

### Referenzliteratur

[11, Environment Agency of England and Wales, 2000, 18, Envirowise (UK) & Entec UK Ltd, 1999]

#### 4.1.8.5.2 Leitfähigkeitsmessung

##### Beschreibung

Leitfähigkeitsmessungen werden zur Bestimmung der Reinheit von Wasser oder der Konzentration von Säuren oder Laugen durch die Ermittlung der Summe der ionischen Bestandteile im Wasser durchgeführt. Elektrodenzellen und induktive Sensoren sind zwei der Sensortypen, die zur Leitfähigkeitsmessung eingesetzt werden.

**Elektrodenzellen** sind Sensoren, die mit direktem Kontakt mit der Prozessflüssigkeit funktionieren, wobei diese Prozessflüssigkeit zwischen zwei Elektrodenplatten hindurchgeleitet wird. Angaben zufolge sind sie sehr genau. Angewandt werden sie u. a. zur Überwachung von Prozesswasser für die Wiederverwendung, wodurch sich die anfallende Abwassermenge minimieren lässt, und für die Überwachung von Kesselwasser, um die Bildung von Kesselstein auf heißen Oberflächen zu minimieren.

Die Leitfähigkeit lässt sich aber auch mit **induktiven Sensoren** messen. Diese kontaktfreien Sensoren haben zwei elektromagnetische Spulen, die die Prozessflüssigkeit umschließen, und sind für hygienische Anwendungen geeignet. Induktive Sensoren verfügen über einen größeren Messbereich als Elektrodenzellen.

##### Erreichbare Umweltvorteile

Geringerer Verbrauch von Wasser und Reinigungsmitteln, geringere Abwassermengen.

##### Betriebsdaten

Auch wenn keine Strömung der Flüssigkeit erforderlich ist, so hat sie doch einen selbstreinigenden Effekt. Lufteinschlüsse sind zu vermeiden. Das Gerät muss in der Lage sein, die temperaturbedingten Leitfähigkeitsschwankungen der Flüssigkeit zu kompensieren.

Siehe auch Abschnitt 4.1.8.4.

In einer Beispielmolkerei (Beispiel A) besteht der CIP-Zyklus aus einer Spülung mit Wasser zur Beseitigung von Produktresten, einem Reinigungsgang mit basischem oder saurem Reinigungsmittel und einem anschließenden weiteren Spülgang mit Wasser. Diese Stufen wurden zuvor durch individuelle Zeitgeber reguliert, um die Menge des verwendeten Reinigungsmittels zu begrenzen. Von jeder CIP-Einheit werden eine Reihe von Prozesslinien und Behältern gereinigt, sodass unterschiedliche Reinigungszyklen bewältigt werden müssen. Der Zeitpunkt für das Öffnen und Schließen der Abflussventile stellte daher eine Kompromisslösung dar, was dazu führte, dass erhebliche Mengen an Reinigungslösung als Abwasser abgegeben wurden.

Es wurden Leitfähigkeitsmessungen eingeführt, um die Zugabe der sauren oder basischen Reinigungslösungen regulierbar zu machen, und um festzustellen, ob Reinigungslösung und/oder Wasser rückgewonnen werden konnten und ob die richtige Menge Reinigungslösung verwendet wurde. Alle bestehenden CIP-Einheiten wurden nachträglich mit Leitfähigkeitssonden ausgestattet. Für neue Einheiten wurde diese Ausstattung gleich vorgesehen.

Zum System gehört eine Leitfähigkeitssonde, die in der Hauptleitung hinter dem Prozessgerät in der Nähe des Einlasses vom Reinigungsmitteltank positioniert ist. Diese Sonde überwacht die Reinigungsmittel-/Wasserkonzentration des Durchflusses durch diese Linie während eines Reinigungszyklus. Die Reinigung mit Reinigungslösung wird durch einen Zeitgeber gestartet, und die Reinigungslösung ersetzt dann nach und nach das Spülwasser im System, das für die Abwasserbehandlung abgeführt wird. Wenn eine voreingestellte Reinigungsmittelkonzentration festgestellt wird, geht von der Sonde ein Signal an einen Schaltantrieb und das Abwasserventil wird geschlossen. Der Flüssigkeitsstrom wird dann zurück in den Reinigungslösungstank geleitet und durch das System zirkuliert anstatt abgelassen zu werden. Anschließend wird von einem Zeitgeber die Spülstufe ausgelöst. Die Reinigungslösung wird in den Lösungstank zurückgeleitet, bis die Verdünnung stattgefunden hat und die voreingestellte Konzentration wieder erreicht ist. In diesem Moment öffnet ein Signal von der Leitfähigkeitssonde das Ablassventil und das Spülwasser wird in Richtung Abwasserbehandlung abgelassen, bis die Sonde erneut sauberes Wasser feststellt.

Das Ablassventil wird dann geschlossen und das saubere Wasser in den Wassertank umgeleitet. Die Leitfähigkeitssonde stellt auch sicher, dass während des gesamten Reinigungsvorgangs die erforderliche Konzentration des Reinigungsmittels beibehalten wird. Es ist nur ein minimaler Einsatz von Arbeitskraft erforderlich. Die Leitfähigkeitssonden werden bis zu einem gewissen Grad bei der Gerätereinigung (CIP) mitgereinigt. Der tägliche Reinigungsmittelverbrauch wird an allen CIP-Einheiten mit einem Durchflussmesser überwacht. Nimmt der Reinigungsmittelverbrauch zu, so ist dies ein Anzeichen dafür, dass die Sonde gründlicher gereinigt werden muss. Das nimmt etwa 10 Minuten Arbeitszeit des Bedienpersonals in Anspruch. Diese zusätzliche Sondenreinigung ist normalerweise alle 4 bis 6 Wochen erforderlich.

Nach Angaben der Molkerei beträgt die Einsparung von Reinigungsmittel schätzungsweise 15 % bei jeder CIP-Einheit; der Wasser- und Reinigungsmittelanfall zur Abwasserbehandlung sowie die Ausfallzeiten der Geräte sind zurückgegangen und die Reinigungsmittelmenge für die verschiedenen Reinigungszyklen wurde optimiert.

In einer anderen Molkerei (Beispiel B) wurden zur Senkung des Reinigungsmittelverbrauchs Leitfähigkeitsmesser installiert. Die Leitfähigkeitssonde erkennt, ob sich Wasser oder Reinigungsmittel in der Leitung befindet und sorgt ggf. dafür, dass Reinigungsmittel in den Rückgewinnungstank umgeleitet wird. Das Ergebnis war die Wiederverwertung des Spülwassers, ein geringerer Verbrauch von Reinigungsmittel und eine entsprechende Senkung des CSB im Abwasser.

#### Anwendbarkeit

Breiter Anwendungsbereich in Prozess- und Reinigungsanwendungen in der Nahrungsmittelproduktion. Beispiele für den Einsatz von Leitfähigkeitsmessungen in der Nahrungsmittelproduktion sind in Tabelle 4.16 aufgeführt. Typische Anwendungen von Leitfähigkeitsmessungen in der Nahrungsmittelproduktion sind in Tabelle 4.17 aufgeführt.

| Aktivität   | Grund für Regulierung  |
|---|--|
| Überwachung der Konzentration gelöster Salze vor der Wasserwiederverwendung | Minimierung des Frischwasserverbrauchs und des Abwasseranfalls   |
| Überwachung von Brunnenwasser   | Minimierung der Produktion von Produkten geringer Qualität (die zu Abfall werden) durch ungeeignetes Prozesswasser |

**Tabelle 4.16: Beispiele für den Einsatz von Leitfähigkeitsmessungen in der Nahrungsmittelproduktion**

| Sektor/Aktivität                        | Anwendung   |
|---|---|
| CIP                                     | Leitfähigkeitsüberwachung zur Steuerung des Anlagenventils anhand der Unterschiede zwischen Produkten, z. B. zwischen Bier und Wasser oder zwischen Natronlauge und Säure |
| Flaschenabfüllung (allgemein)           | Leitfähigkeitsüberwachung des Einsatzes von Natronlauge in Reinigungslösungen für Flaschen  |
| Produktüberwachung (induktive Sensoren) | Überall in der Getränkeindustrie und in Molkereien  |

**Tabelle 4.17: Typische Anwendungen der Leitfähigkeitsmessung in der Nahrungsmittelproduktion**

#### Wirtschaftlichkeit

Die Molkerei in Beispiel A berichtet über Reinigungsmittelsparungen im Wert von 13.000 GBP/Jahr. Damit betrug die Amortisationsdauer laut Unternehmensangaben 16 Monate.

Die Molkerei in Beispiel B gab Einsparungen von 10.000 GBP/Jahr und eine Amortisationsdauer für die Investition von 4 Monaten an.

#### Anlass für die Umsetzung

Geringerer Verbrauch von Reinigungsmitteln.

#### Beispielanlagen

Zahlreiche Anlagen in der Getränkeindustrie und Milchwirtschaft und solche, in denen CIP eingesetzt wird.

### Referenzliteratur

[11, Environment Agency of England and Wales, 2000, 18, Envirowise (UK) & Entec UK Ltd, 1999]

#### **4.1.8.5.3 Trübungsmessung**

##### Beschreibung

Streulicht-Trübungsmessgeräte nutzen ein Lichtdiffusionsverfahren, um das Licht zu messen, das von den in Flüssigkeit vorhandenen Teilchen oder Blasen durch einen rechten Winkel gestreut wird. Diese Methode wird für Messungen geringer bis mittlerer Trübungen eingesetzt, u. a. auch für die Trübungsmessung in destilliertem Wasser. Wenn sich das Trübungsmessgerät nicht einfach in einer Prozesslinie installieren lässt, können Probennehmer verwendet werden. Dadurch lässt sich die Hygiene verbessern.

Schwebstoff-Trübungsmesser arbeiten mit einer Lichtabsorptionmethode. Dabei wird die Lichtmenge gemessen, die durch die in der Prozessflüssigkeit enthaltene Materie dringt. Diese Geräte werden zur Messung mittlerer bis starker Trübungen verwendet.

##### Erreichbare Umweltvorteile

Weniger Materialverluste bei der Verarbeitung, stärkere Wiederverwendung von Wasser und weniger Abwasseranfall.

##### Betriebsdaten

Trübungsmesser sollten vorzugsweise in vertikalen Leitungen mit aufwärts gerichteter Strömung installiert werden. Der optische Teil sollte der Strömungsbewegung zugewandt sein, damit ein möglichst großer Selbstreinigungseffekt erzielt wird. In horizontal verlaufenden Leitungen sollten die Messgeräte an der Seite, nicht unten oder oben installiert werden, um Fehlmessungen durch schwebende oder abgesetzte Teilchen und Verschmutzungen durch Ablagerungen bzw. schwebende Teilchen zu vermeiden. Zur Vermeidung von fehlerhaften Messungen sollte die Strömungsgeschwindigkeit in der Flüssigkeit 2 m/s nicht übersteigen. Zur Minimierung der Strahlstreuung sollten Gasblasen und Entgasen vermieden werden.

In einem Nahrungsmittelproduktionsprozess gab es Berichten zufolge während der Trennungsstadien Produktverluste an das Abwasser, was zu einer Nichteinhaltung der Einleitungsbedingungen für das Abwasser des Unternehmens führte. Durch die Installation eines hygienischen Trübungsmessgeräts und eines Durchflussmessers konnten die Produktverluste an das Abwasser gesenkt, die Produktausbeute erhöht und finanzielle Einsparungen erzielt werden.

In derselben Molkerei wie in Beispiel A im Abschnitt 4.1.8.5.2 wird Molke, ein Nebenprodukt der Käseherstellung, in einem Evaporationsschritt konzentriert, bevor durch Sprühtrocknung Molkepulver hergestellt wird. Die Evaporatoren werden regelmäßig einer CIP-Reinigung unterzogen, wozu auch das Herausspülen von Rückständen der konzentrierten Molke vor der Reinigung mit Reinigungsmitteln zählt, d. h., es gibt einen Vorreinigungsschritt. Beim Abkoppeln des Verdampfers aus dem Prozess für die CIP-Reinigung wurde immer eine erhebliche Molkemenge an das Abwasser verloren.

Als Teil eines automatischen Rückgewinnungssystems wurde am Ende der Befüllungsleitung des Konzentrationstanks eine Trübungsmesssonde installiert. Mit der Sonde wird das Vorliegen von Wasser-/Molkegemischen festgestellt, und die Daten werden an das Steuersystem übermittelt. Die Rückführung der konzentrierten Molke in den Molkelagertank wird dann über ein Densimeter gesteuert, während die Trübungsmesssonde die Rückführung des Wasser-Molke-Gemischs in einen separaten Tank steuert. Anschließend wird das Gemisch mit Rohmolke für die Wiederaufbereitung gemischt. Wenn die Trübung zwischen zwei bestimmten Einstellwerten liegt und damit anzeigt, dass Molke vorhanden ist, wird der Strom automatisch über Steuerventile in den Rückgewinnungstank umgeleitet. Wenn der Reinigungsmittelzyklus einsetzt, wird das Sondersignal ignoriert, um sicherzustellen, dass kein saures oder basisches Reinigungsmittel in den Molketank gelangt. So wird die Kontamination der rückgewonnenen Molke vermieden und nur sauberes Wasser oder Wasser mit Reinigungsmittel wird zur Abwasserbehandlung abgegeben. Abbildung 4.9 zeigt den Molkerückgewinnungsprozess.

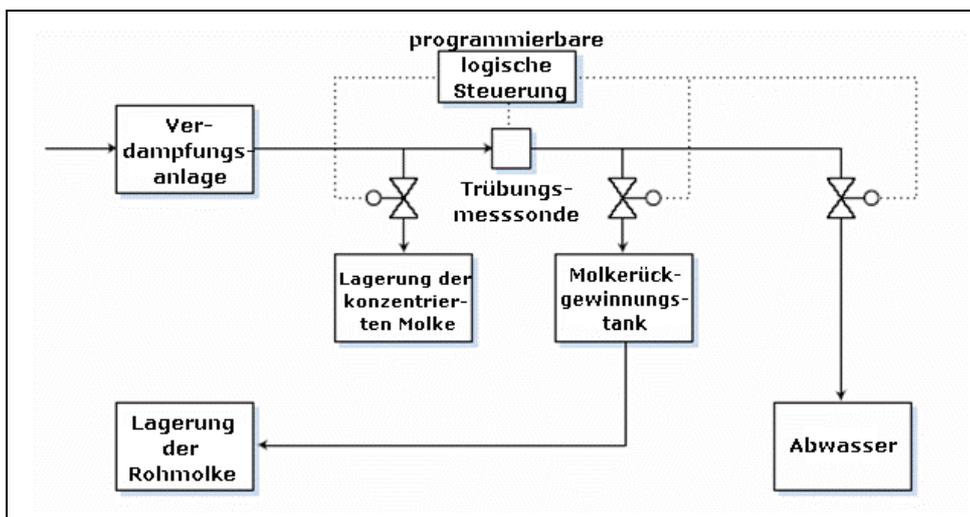


Abbildung 4.9: Molkerückgewinnung unter Einsatz der Trübungsmessung

Angaben zufolge sind seit Einrichtung des Molkerückgewinnungssystems 1996 keine Probleme aufgetreten. Bei der Installation des Systems wurde eine Bedienschulung durchgeführt, mit der die zuständigen Mitarbeiter über Funktionsweise und Vorteile des neuen Systems informiert wurden. Die Betriebskosten sind den Angaben zufolge vernachlässigbar und die Trübungsmesssonde erfordert nur geringen Wartungsaufwand. Die Sonde wird an Ort und Stelle (CIP) gereinigt, wenn der Hauptverdampfer gereinigt wird. Eine regelmäßige geplante Wartung wird jährlich durchgeführt. Zu den Vorteilen zählen Kostenersparnis, größere Produktausbeute, weniger Molkeverlust ans Abwasser und geringere Kläranlagenkosten.

Anwendbarkeit

Anwendbar, wenn die Produktausbeute durch Rückgewinnung aus Prozesswasser gesteigert werden kann sowie für die Wiederverwendung von Reinigungswasser.

Beispiele für den Einsatz von Trübungsmessungen in der Nahrungsmittelproduktion sind in Tabelle 4.18 aufgeführt.

| Aktivität                                  | Grund für Regulierung   |
|--|---|
| Überwachung der Qualität von Prozesswasser | Minimierung von Abwasser durch nicht anforderungsgerechtes Prozesswasser oder nicht anforderungsgerechte Produkte |
| Überwachung von CIP-Systemen               | Optimierte Wiederverwendung von Reinigungswasser und dadurch weniger Abwasser                                     |

Tabelle 4.18: Beispiele für den Einsatz von Trübungsmessungen in der Nahrungsmittelproduktion

Eine typische Anwendung der Trübungsmessung in der Nahrungsmittelproduktion ist die Überwachung von Prozessabwasserströmen zur Ermittlung der Eignung für die Rückgewinnung für den Prozess.

Wirtschaftlichkeit

Das oben genannte Lebensmittelherstellungsunternehmen gab an, dass der Rückgang der Abwasserbehandlungskosten und die Einsparungen mehr als 100.000 GBP/Jahr betragen.

Die Molkerei aus Beispiel A nannte Einsparungen von rund 16.000 GBP/Jahr und einen Amortisationszeitraum von 8 Monaten für Investitions- und Installationskosten zusammen.

Anlass für die Umsetzung

Weniger Produktverluste.

### Beispielanlagen

Mindestens eine Molkerei, in der Käse hergestellt wird, und eine weitere nicht näher bezeichnete Anlage, in der Lebensmittel hergestellt werden, im Vereinigten Königreich.

### Referenzliteratur

[11, Environment Agency of England and Wales, 2000, 18, Envirowise (UK) & Entec UK Ltd, 1999]

#### **4.1.8.6 Einsatz automatischer Wasserregler**

##### Beschreibung

Sensoren, wie beispielsweise Fotozellen, können installiert werden, damit das Vorhandensein von Material erkannt wird und die Wasserzufuhr nur bei Bedarf erfolgt. Beim Produktwechsel und während sämtlicher Pausen kann die Wasserzufuhr automatisch abgestellt werden.

##### Erreichbare Umweltvorteile

Geringerer Wasserverbrauch, weniger zu klärendes Abwasser, und bei Regulierung des Drucks auch weniger Einschleppung von biologischem Material und Kontaminationen.

##### Betriebsdaten

Durch sorgfältige Auswahl, Installation und Wartung der Fotozellen wird deren zuverlässiges Funktionieren gewährleistet. Durch richtige Positionierung wird dafür gesorgt, dass Produkte nicht intensiver als nötig gewaschen werden.

Bei dieser Technik wird davon ausgegangen, dass jedes erkannte Produkt gewaschen werden muss; sie unterscheidet nicht zwischen sauberen und schmutzigen Produkten.

##### Anwendbarkeit

Anwendbar, wo keine ununterbrochene Wasserzufuhr benötigt wird.

##### Anlass für die Umsetzung

Geringere Wasserkosten.

##### Referenzliteratur

[1, CIAA, 2002]

#### **4.1.8.7 Einsatz von Regelungsvorrichtungen**

##### Beschreibung

Ventile sind die häufigsten Regelungsvorrichtungen und werden in großem Umfang sowohl in manuellen als auch automatischen Regelsystemen eingesetzt. Ventile werden oft verwendet, um eine Strömungsgeschwindigkeit zwecks Steuerung eines anderen Prozessparameters zu verändern. So kann beispielsweise die Temperatur von Schokolade gemessen und bei Bedarf durch Regelung der Strömungsgeschwindigkeit von wärmendem und kühlendem Wasser angepasst werden. Als Beispiele seien Durchflussregler und Magnetventile genannt, aber es sind auch Regelungsvorrichtungen möglich.

Durchflussregler werden verwendet, um einen konstanten Fluss mit einer voreingestellten Geschwindigkeit zu erzeugen. Der Fluss durch den Regler kann innerhalb eines begrenzten Bereichs angepasst werden, aber diese Geräte sind darauf ausgelegt, dass nicht oft Anpassungen erfolgen.

Magnetventile sind Vorrichtungen mit zwei Positionen, in denen ein Magnet dazu verwendet wird, ein Ventil auf ein Steuersignal hin zu öffnen oder zu schließen.

##### Erreichbare Umweltvorteile

Verringerter Wasser- und entsprechend verringerter Energieverbrauch.

##### Betriebsdaten

Ein als Beispiel genanntes Lebensmittelherstellungsunternehmen erkannte, dass der übermäßige Wasserverbrauch seiner Vakuumpumpen dadurch verursacht wurde, dass der Durchfluss des Sperrwassers höher war als notwendig.

Die maximale Durchflussrate der Serviceflüssigkeit, die nur 2,7 m<sup>3</sup>/h betragen sollte, lag tatsächlich bei fast 11,5 m<sup>3</sup>/h, war also mehr als viermal so hoch wie erforderlich.

Durch die Installation von Konstantflussventilen zur Sicherung der richtigen Zuflussgeschwindigkeit zu den einzelnen Wasserringvakuumpumpen wurde der Wasserverbrauch um ungefähr 60.000 m<sup>3</sup>/Jahr reduziert, was 7,5 % des Leitungswasserverbrauchs der Anlage entspricht. Die Wasser- und Abwasserkosten sanken, es wurde weniger Energie verbraucht und die Abnutzung der Vakuumpumpen war geringer.

In einem Beispielunternehmen, das Hähnchen verarbeitet, wurde ein übermäßiger Wasserverbrauch festgestellt. Es wurden Durchflussregler installiert, um die Wasserzufuhr für bestimmte Prozesse auf die erforderliche Zufuhr rate einzustellen und dadurch den Wasserverbrauch zu senken.

Ein Beispielunternehmen, das Fische verarbeitet, installierte ein Magnetventilsystem an der Wasserzufuhr für ein Vorwaschsystem. Zuvor war das Wasser durchgehend geflossen, was zu Überlaufen und Eintrag von Resten in das Abwasser geführt hatte. Durch das Magnetventil konnte die Wasserzufuhr abgeschaltet werden, wenn das Förderband nicht in Betrieb war. Der Wasserverbrauch in diesem Prozess ging um 40 % zurück.

#### Anwendbarkeit

Durchflussregler sind in vielen Bereichen einsetzbar, wo ein konstanter Durchfluss mit voreingestellter Rate benötigt wird.

Magnetventile können in der Nahrungsmittelproduktion überall eingesetzt werden und finden oft Verwendung zur Steuerung der Wasserzufuhr.

#### Wirtschaftlichkeit

Die Einführung der konstanten Durchflussventile in der erwähnten Lebensmittelproduktionsanlage führte zu einem Kostenrückgang um 70.000 GBP/Jahr, was einer Amortisationsdauer für die Investition von weniger als einem Monat entsprach.

In der Hähnchenverarbeitungsanlage kostete die Einführung der Durchflussregler weniger als 1.000 GBP und führte zu Wassereinsparungen im Wert von mehr als 10.000 GBP/Jahr.

In der Fischverarbeitungsanlage bedeutete der 40-%ige Rückgang des Wasserverbrauchs eine Einsparung von 2.500 GBP/Jahr, was einem Amortisationszeitraum von 5 Wochen entsprach.

#### Anlass für die Umsetzung

Geringerer Wasserverbrauch und damit geringere Kosten.

#### Beispielanlagen

In der Nahrungsmittelproduktion weit verbreitet.

#### Referenzliteratur

[11, Environment Agency of England and Wales, 2000, 18, Envirowise (UK) & Entec UK Ltd, 1999]

### **4.1.8.8 Einsatz von Wasserdüsen**

#### Beschreibung

In der Nahrungsmittelproduktion ist der Einsatz von Wasserdüsen z. B. für das Waschen und manchmal das Auftauen der Produkte und für die Reinigung von Geräten während der Verarbeitung weit verbreitet (siehe Abschnitt 4.3.7.1). Wasserverbrauch und Abwasserverschmutzung lassen sich minimieren, indem die Düsen richtig positioniert und ausgerichtet werden. Mit dem Einsatz von präsenzaktivierten Sensoren und insbesondere mit deren Installation in den richtigen Positionen kann sichergestellt werden, dass Wasser nur dort verbraucht wird, wo es nötig ist. Durch die Entfernung von Düsen und ihren Ersatz durch mechanische Geräte an Stellen, an denen Wasser für das Leiten von Lebensmitteln eingesetzt wird, kann der Wasserverbrauch gesenkt und der Eintrag von Lebensmittelteilchen in das Wasser, das dann in einer Kläranlage behandelt werden muss, verringert werden.

Außerdem lässt sich der Wasserverbrauch optimieren, indem der Wasserdruck der Wasserdüsen überwacht und konstant gehalten wird. Der Wasserdruck kann für die Betriebseinheit eingestellt werden, die den höchsten Druck benötigt. Entsprechende Druckregulierer können in den anderen Betriebseinheiten, die Wasser benötigen, installiert werden.

### Erreichbare Umweltvorteile

Verringerung von Wasserverbrauch und Abwasseranfall. Weniger Abwasserverschmutzung, z. B. durch kürzere Berührungszeiten zwischen Lebensmittel und Wasser.

### Betriebsdaten

Bei der Verarbeitung von Wiener Würstchen ist nach dem Räuchern ein Abkühlen erforderlich. Das wird normalerweise dadurch erreicht, dass die Würstchen in der Räucherammer oder in einem eigens dafür vorgesehenen Bereich abgespült werden. Bei Verwendung von Beregnungsleitungen wird für diesen Zweck oft eine große Wassermenge verbraucht. Der Wasserverbrauch liegt im Allgemeinen bei 3,5 m<sup>3</sup>/t. Angaben zufolge werden an Stelle von Beregnungsleitungen auch wassersparende Düsen und eine Zeitsteuerung eingesetzt. Um unnötige Verluste zu vermeiden, müssen die Düsen richtig positioniert und ausgerichtet sein, damit das Wasser die Würstchen optimal trifft. Wird das Abkühlen in eigens für diesen Vorgang geplanten Kammern durchgeführt, so können die Würstchen mit fein zerstäubtem Wasser besprüht werden. Anschließend wird die Wasserzufuhr unterbrochen und Luft durch die Kammer gesaugt. Dadurch verdunstet das Wasser auf den Wurstoberflächen. Wenn die Oberflächen trocken werden, wird ein neuer Zyklus von Sprühen und Trocknen gestartet. Diese Methode bewirkt erhebliche Wassereinsparungen.

Düsen werden auch bei der Vakuumverpackung von Würstchen eingesetzt. Eine Vakuumverpackungsmaschine braucht Kühlwasser, und zwar etwa 0,2 m<sup>3</sup>/t Wurst. Durch die Einstellung der Wassermenge und die Festeinstellung der Düsenpositionen wird der Wasserverbrauch minimiert. Eine andere Möglichkeit besteht im Auffangen und Wiederverwenden des Kühlwassers.

Im Fischsektor wird über einen Rückgang des Wasserverbrauchs um etwa 0,13 bis 0,2 m<sup>3</sup>/t Rohmaterial berichtet.

Beim Filetieren von Weißfisch kann der Wasserverbrauch um bis zu 90 % gesenkt werden, wenn Düsen installiert und das Wasser nur in einer oder zwei von jeweils drei Sekunden versprüht wird. Bei der Sortierung von Hering und Makrelen lässt sich eine Senkung des Wasserverbrauchs um 50 % bis 65 % erzielen, wenn die Düsengrößen so reguliert werden, dass sie nur die erforderliche Wassermenge abgeben.

Beim Enthäuten und Schneiden von Fisch kann Berichten zufolge die Reduzierung von Anzahl und Größe der Sprühdüsen zu Wassereinsparungen von etwa 75 % führen. Beim Filetieren von Fisch lässt sich Angaben zufolge eine Senkung des Wasserverbrauchs um 60 % bis 75 % erzielen, wenn die folgenden Maßnahmen durchgeführt werden, die eine Kombination aus geplantem Düseneinsatz und anderen Techniken darstellen:

- Beseitigung unnötiger Wasserdüsen
- Verwendung von Wasserdüsen statt Wasserleitungen für das Waschen des Produkts
- Verwendung mechanischer Vorrichtungen statt Wasserdüsen zum Weitertransport des Fisches nach dem Schwanzschnitt
- Ersatz der Düsen für das Waschen der Antriebsräder des Filetierteils durch mechanische Schaber
- Austausch vorhandener Düsen gegen Düsen mit niedrigerem Wasserverbrauch
- Einsatz pulsierender Wasserdüsen, d. h. abwechselndes Öffnen und Schließen der Wasserversorgung mit Hilfe eines automatischen Ventils
- Austausch der Abfallrinne durch Siebförderbänder und Verschluss der Düsen in der Abfallrinne. Der Abfall wird direkt bei der Filetiermaschine vom Prozesswasser getrennt, dadurch geringere Kontaktzeiten und geringere Einträge von z. B. Fett (siehe Abschnitt 4.7.2.6 )
- Einsatz präsenzaktivierter Sensoren zur Steuerung des Düsenbetriebs
- Verwendung trockener Transportmethoden für Eingeweide und Fett (siehe Abschnitt 4.7.2.6)
- Entfernen von Haut und Fett aus der Enthütungstrommel mittels Vakuum (siehe Abschnitt 4.7.2.4)

Das Skelett kann mit zwei Sätzen rotierender Messer von den Fischfilets abgetrennt werden. Die Messer müssen möglicherweise mit Wasser aus Düsen gekühlt werden, wodurch auch Fischfleisch und Schuppen entfernt werden; dies kann allerdings auch mechanisch geschehen.

Anwendbarkeit

Überall in der Nahrungsmittelproduktion anwendbar. Im Fischsektor werden Düsen beim Schuppen, Enthäuten, Zerlegen, Ausnehmen und Filetieren verwendet. Im Fleischsektor kommen sie in der Wurstverarbeitung zum Einsatz. In Brauereien werden sie zur Reinigung von Fässern und Flaschen verwendet.

Beispielanlagen

Anwendung in der dänischen Heringsindustrie (siehe Abschnitt 4.7.2.9.1).

Referenzliteratur

[28, Nordic Council of Ministers, 1997, 41, Nordic Council of Ministers, 2001, 134, AWARENET, 2002]

**4.1.9 Materialauswahl****4.1.9.1 Auswahl von Rohmaterial für die Nahrungsmittelproduktion zur Minimierung von festen Abfällen und schädlichen Emissionen in Luft und Wasser**Beschreibung

Ein Teil praktisch sämtlicher verwendeter Roh- und Hilfsstoffe wird zu Festabfall oder gelangt in die Kläranlage eines Standortes. Hilfsmaterialien sind solche Materialien, die bei der Verarbeitung von Rohstoffen verwendet werden und nicht ins Endprodukt gelangen, wie z. B. Reinigungsmittel. Die Mehrzahl der in der Nahrungsmittelproduktion verwendeten Rohstoffe ist natürlichen Ursprungs und hat üblicherweise einen hohen Anteil an organischer Substanz; ihre Auswirkungen auf die örtliche terrestrische und aquatische Umwelt können erheblich sein.

In der Praxis ist die Möglichkeit der Verwendung verschiedener Rohstoffe oft eingeschränkt, da die Stoffe in den Rezepten vorgegeben sind und es oft nur wenige oder gar keine Alternativen gibt. In manchen Branchen wird versucht, Rohstoffe zu verwenden, bei denen weniger Nebenprodukte und Abfälle entstehen.

Mit der Auswahl frischer Materialien und von Materialien, die den Qualitätsstandards für die Verarbeitung in der Anlage genügen, bevor die Materialien in der Anlage entgegengenommen werden, kann die Abfallmenge reduziert werden, die z. B. durch die Entsorgung von überreifem Obst und Gemüse oder von Fisch, dessen Zersetzung bereits begonnen hat und der für die Verarbeitung nicht geeignet ist, anfällt. Dazu ist es hilfreich, wenn mit dem Erzeuger/Lieferanten Absprachen z. B. über Erntezeitpunkt, Ernteproduktion und Ernteverarbeitung getroffen werden. Außerdem können Vereinbarungen über den Einsatz von Pflanzenschutzmitteln getroffen werden, z. B. über den Verzicht auf ihre Verwendung rechtzeitig vor der Ernte, damit die Kontamination des Abwassers beim Waschen von Obst und Gemüse verringert wird.

Erreichbare Umweltvorteile

Geringere Verschwendung von Rohmaterial, weniger Abwasserkontamination und weniger Geruchsemissionen.

Betriebsdaten

Es können Vorgaben für Rohstoffe mit dem Lieferanten vereinbart werden, und Rohmaterialien, die diesen Vorgaben nicht entsprechen, können bei Anlieferung in der Nahrungsmittelproduktionsanlage zurückgewiesen und an den Herkunftsort zurückgeschickt werden. Dadurch lässt sich der Anteil an Rohmaterial erhöhen, der ins Produkt gelangt, bzw. der Anteil senken, der zu Abfall oder zu einem geringerwertigen Nebenprodukt wie z. B. Tierfutter wird.

Erreichen lässt sich das, indem der Lieferant eine Qualitätskontrolle durchführt und der Betreiber in den Anlagen der Nahrungsmittelverarbeitung Qualitätsüberprüfungen vornimmt. In Molkereien beispielsweise gehört dieses Vorgehen zur Routine. Die Milch wird in Tanklastwagen angeliefert und das Molkereipersonal führt eine Sicht- und Geruchsprüfung der Milch und Labortests durch. Wenn die Milch nicht den Anforderungen genügt, wird sie nicht angenommen.

Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

Anlass für die Umsetzung

Maximierung der Produktausbeute und Minimierung der Abfallentsorgungskosten.

### Referenzliteratur

[31, VITO, et al., 2001]

#### **4.1.9.2 Auswahl der verwendeten Hilfsmaterialien**

Auch Chemikalien werden in Lebensmittelherstellungsprozessen eingesetzt (z. B. bei der Laugenschälung, Härtung von Pflanzenöl, Gerinnung, Alkalisierung, Neutralisation). Für einige der Stoffe, die in Lebensmittelherstellungsprozessen verwendet werden, gibt es eine EU-weite Zusammenstellung der Risikobewertungen nach der EU-Altstoffverordnung (793/93/EWG). Diese Risikobewertungen erstrecken sich auf Umwelt- und Gesundheitsrisiken. Für Stoffe, die nicht nach 793/93/EWG bewertet wurden, müssen Angaben zu Gefahren und Risiken aus anderen Quellen beschafft werden, um sicherzustellen, dass Risiken minimiert und, sofern dies praktikabel ist, weniger gefährliche Alternativen gewählt werden [199, Finland, 2003]. Ein Beispiel ist die für Deutschland entwickelte Risikobewertungs- und -managementstrategie [154, Ahlers J. et al., 2002].

Für karzinogene, mutagene und teratogene Einsatzstoffe können Ersatzstoffe verwendet werden.

#### **4.1.9.3 Vermeidung des Gebrauchs von Ozonschicht schädigenden Stoffen, wie z. B. halogenierten Kältemitteln**

##### Beschreibung

In der Nahrungsmittelproduktion sind Kältemittel für Abkühlung, kühle Lagerung und Tiefkühlung weit verbreitet. Die Wechselwirkungen zwischen halogenierten Kältemitteln und dem Ozon in der Luft haben dazu geführt, dass das Verbot des Inverkehrbringens und Gebrauchs von Ozonschicht schädigenden Substanzen und solche Substanzen enthaltenden Produkten und Geräten immer stärker ausgeweitet wurde [202, EC, 2000]. Derzeit liegt ein Vorschlag für eine Verordnung des Europäischen Parlaments und des Rats über bestimmte fluorierte Treibhausgase vor [246, EC, 2003].

Diese Verbindungen sind durch andere Kältemittel wie Ammoniak und Glykol und in manchen Fällen auch durch gekühltes Wasser ersetzt worden.

##### Erreichbare Umweltvorteile

Verringerung der Gefahr eines Ozonabbaus und der globalen Erwärmung.

##### Medienübergreifende Effekte

Risiko von Ammoniak- und Glykoleckagen, die Gesundheit und Sicherheit gefährden können.

##### Betriebsdaten

Der Gebrauch von Ozonschicht schädigenden Substanzen kann durch folgende Maßnahmen verhindert oder minimiert werden [65, Germany, 2002]:

- Verwendung von Ersatzstoffen
- Verwendung von geschlossenen Kreisläufen, wenn Ozonschicht schädigende Stoffe eingesetzt werden
- Einschluss von Systemen in Gebäuden
- Einkapselung von Systemteilen
- Erzeugung eines Unterdrucks im eingekapselten Bereich, um Leckagen in Systemen zu verhindern
- Auffangen der Substanzen bei der Abfallbehandlung
- Einsatz optimierter Techniken zur Abgasreinigung
- Sachgerechter Umgang mit den rückgewonnenen Substanzen und dem Abfall.

##### Anlass für die Umsetzung

Gesetzliche Vorgaben.

## 4.2 Techniken, die in einer Reihe von Branchen der Nahrungsmittelproduktion anwendbar sind (strukturiert wie Kapitel 2 und 3)

### 4.2.1 Annahme, Handhabung und Lagerung von Material

#### 4.2.1.1 Abschalten von Motor und Kühleinheit von Fahrzeugen beim Be- und Entladen und im geparkten Zustand

##### Beschreibung

Laufende Motoren und Kühleinheiten von Fahrzeugen können eine Lärmbelastigung darstellen. Das lässt sich vermeiden, wenn diese beim Be- und Entladen und im geparkten Zustand abgeschaltet werden. Wenn im Fahrzeug weiterhin Kühl- oder Gefriertemperaturen herrschen müssen, lässt sich dies durch Stromversorgung aus der Anlage erreichen.

##### Erreichbare Umweltvorteile

Verringerte Lärmemissionen.

##### Anwendbarkeit

Anwendbar beim Be- und Entladen von Kühl- und anderen Fahrzeugen.

##### Anlass für die Umsetzung

Verringerte Lärmemissionen.

##### Referenzliteratur

[31, VITO, et al., 2001]

### 4.2.2 Auftauen

#### 4.2.2.1 Auftauen mittels Rückführung und Bewegung mit Luft

##### Beschreibung

Das für das Auftauen verwendete Wasser wird in einem geschlossenen Kreislauf rezirkuliert und wieder verwendet. Während des Auftauens wird das Wasser mit Hilfe von Luft in Bewegung gehalten. Durch den Einbau von Füllstandsanzeigern kann die Wassermenge, die in das Becken eingespeist wird, reguliert werden. Bei Krabben und Garnelen kann gefiltertes Schälwasser verwendet werden.

##### Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs. Geringere Abwassermenge und -verschmutzung.

##### Medienübergreifende Effekte

Energieverbrauch.

##### Betriebsdaten

Im Fischsektor wird im Vergleich zum Betrieb mit laufendem Wasser eine Abnahme des Wasserverbrauchs von 5 m<sup>3</sup>/t auf 2 m<sup>3</sup>/t Rohfisch angegeben.

##### Anwendbarkeit

Anwendbar im Fleischsektor und im Fischsektor für Makrelen, Krabben und Garnelen.

##### Referenzliteratur

[134, AWARENET, 2002, 182, Germany, 2003]

#### 4.2.2.2 Auftauen in Behältern mit warmem Wasser und Luftblasen am Boden

##### Beschreibung

Das Auftauen erfolgt in Behältern, die mit etwa 30 - 35 °C warmem Wasser gefüllt sind und in am Boden Luftblasen eingeleitet werden. Durch den Einbau von Füllstandsanzeigern kann die Wassermenge, die in das Becken eingespeist wird, reguliert werden. Der Wasserstrom wirkt sich auch auf die Temperatur aus. Bei Krabben und Garnelen kann gefiltertes Schälwasser verwendet werden.

### Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs. Geringere Abwassermenge und -verschmutzung.

### Medienübergreifende Effekte

Energieverbrauch.

### Betriebsdaten

In einer dänischen Fischverarbeitungsanlage wurde ein Rückgang des Wasserverbrauchs um bis zu 60 % im Vergleich zum Auftauen in fließendem Wasser erzielt. Der Wasserverbrauch ging von 5 m<sup>3</sup>/t Rohfisch auf 1,8 - 2,2 m<sup>3</sup>/t zurück.

### Anwendbarkeit

Anwendbar im Fleischsektor und im Fischsektor für Weißfisch, Krabben und Garnelen.

### Wirtschaftlichkeit

In dem dänischen Beispiel wurden die Kosten für eine Anlage mit einer Kapazität von 18 Tonnen Rohfisch pro Tag (entspricht 3.600 Tonnen/Jahr) auf etwa 300.000 DKK geschätzt. Die Kosteneinsparung durch geringeren Wasserverbrauch betrug 10.800 DKK.

### Anlass für die Umsetzung

Kosteneinsparung durch geringeren Wasserverbrauch.

### Beispielanlagen

Wird in mindestens einer Fischverarbeitungsanlage in Dänemark eingesetzt.

### Referenzliteratur

[28, Nordic Council of Ministers, 1997, 134, AWARENET, 2002]

## **4.2.2.3 Auftauen durch Berieselung**

### Beschreibung

Das Auftauen wird durch das Berieseln der Lebensmittel mit Wasser bewirkt.

### Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs. Geringere Abwassermenge und -verschmutzung.

### Medienübergreifende Effekte

Die Lebensmitteloberfläche kann austrocknen, sodass ungesättigte Fettsäuren, z. B. in Schweinefleisch, oxidieren können.

### Betriebsdaten

Im Vergleich zum Auftauen durch Eintauchen in fließendes Wasser wird mit dieser Technik weniger Wasser verbraucht, aber es wird mehr Zeit benötigt und es sind größere Oberflächen erforderlich.

### Anwendbarkeit

Anwendbar im Fleisch- und im Fischsektor.

### Referenzliteratur

[134, AWARENET, 2002]

## **4.2.2.4 Auftauen mit 100 % wassergesättigter gewärmter Luft**

### Beschreibung

Das Auftauen wird durch Kontakt des Lebensmittels mit heißer oder warmer Luft bewirkt, die zu 100 % mit Wasser gesättigt ist.

### Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs. Geringere Abwassermenge und -verschmutzung.

Medienübergreifende Effekte

Zur Erzeugung der Luftblasen wird Energie verbraucht.

Betriebsdaten

Im Vergleich zum Auftauen durch Eintauchen in fließendes Wasser wird mit dieser Technik weniger Wasser verbraucht, aber es wird mehr Zeit benötigt und es sind größere Oberflächen erforderlich.

Durch die Verwendung heißer Luft kann es auf den Oberflächenschichten des aufgetauten Produkts zu schnellem Mikroorganismenwachstum kommen, und die Reabsorption von aufgetautem Wasser kann verhindert werden. Dadurch entstehen unschöne und oft hinsichtlich des Nährstoffgehalts verschwenderische Tropfverluste. Außerdem kann die Lebensmitteloberfläche austrocknen, sodass ungesättigte Fettsäuren, z. B. in Schweinefleisch, oxidieren können. Der Energieverbrauch ist wegen des Einsatzes heißer Luft höher als bei anderen Auftautechniken.

Wenn warme und feuchte Luft zum Auftauen von Blöcken gefrorenen Weißfischs verwendet wird, kann es zu Problemen mit der konstanten Qualität des Endprodukts kommen, da die Fische an den Seiten des gefrorenen Blocks schneller auftauen als die Fische in der Mitte.

Es wird berichtet, dass trockenes Auftauen sich negativ auf die Qualität von Krabben und Garnelen auswirkt.

Anwendbarkeit

Anwendbar im Fleisch- und im Fischsektor.

Beispielanlagen

Wird oft in der Weißfischverarbeitung in den nordischen Ländern eingesetzt.

Referenzliteratur

[28, Nordic Council of Ministers, 1997, 134, AWARENET, 2002]

**4.2.2.5 Auftauen an der Luft**Beschreibung

Das Auftauen erfolgt in einem Kaltraum bei geregelter Temperatur über 18 - 24 Stunden.

Erreichbare Umweltvorteile

Verringerung von Wasserverbrauch und Abwasserentstehung.

Medienübergreifende Effekte

Zur Aufrechterhaltung der geregelten Temperatur des Kaltraums wird Energie verbraucht.

Betriebsdaten

Angaben zufolge werden beim Auftauen von Fleisch in mit Wasser gefüllten Behältern die Fleischsäfte entzogen und Proteine abgebaut. Für die Fleischqualität ist angabegemäß das Auftauen in einer Klimakammer bei 0 °C besser; es erfordert aber mehr Zeit und größere Oberflächen. Die Fleischoberfläche kann austrocknen, und ungesättigte Fettsäuren im Schweinefleisch können oxidieren. Es kann zu Tropfverlusten von Fleischsäften kommen.

Anwendbarkeit

Anwendbar in der Fleischverarbeitung.

Referenzliteratur

[254, Denmark, 2005]

**4.2.3 Zentrifugation/Separation****4.2.3.1 Minimierung des Anfalls von Abfall aus Zentrifugalabscheidern**Beschreibung

Sowohl Häufigkeit als auch Volumen der Abfallanfalls aus Zentrifugen sind üblicherweise vom Hersteller des Geräts angegeben. Wenn diese Daten vorliegen, kann die tatsächliche Leistung gegenüber diesen Angaben

abgeglichen werden. Wenn das Gerät mit der angegebenen Leistung betrieben wird, lässt sich möglicherweise die Menge der als Abfall entsorgten Phase verringern und diejenige der als Produkt zurückbehaltenen Phase vergrößern, ohne dass Qualitäts- und Hygienestandards verletzt werden. Dies ist durch enge Zusammenarbeit mit dem Qualitätssicherungspersonal möglich.

### Erreichbare Umweltvorteile

Weniger Verschwendung von Rohstoffen.

### Betriebsdaten

Angaben zufolge geht in Molkereien 1 % der angelieferten Rohmilch verloren, und davon 0,1 % bei der Milchverarbeitung, und hiervon wiederum der größte Teil bei der Zentrifugalabscheidung.

### Anwendbarkeit

Für alle Zentrifugalabscheider anwendbar.

### Anlass für die Umsetzung

Weniger Verluste an Rohstoffen und größere Ausbeute.

### Referenzliteratur

[11, Environment Agency of England and Wales, 2000]

## 4.2.4 Fermentierung

### 4.2.4.1 Rückgewinnung und Aufreinigung von Kohlendioxid

#### Beschreibung

Das im Fermentationsprozess erzeugte CO<sub>2</sub> kann aufgefangen, gereinigt, komprimiert, getrocknet, aufgereinigt und verflüssigt werden. Es lässt sich dann nutzen.

Das während der Fermentierung freigesetzte CO<sub>2</sub> wird an eine Rückgewinnungseinheit weitergeleitet. Das CO<sub>2</sub>, das rückgewonnen werden soll, enthält sämtliche flüchtigen Bestandteile, die während der Fermentierung vorliegen oder entstehen, darunter Sauerstoff, Fuselöle und Carbonyl- und Schwefelsubstanzen mit sehr geringen Geschmacksschwellen, wie z. B. Schwefelwasserstoff. Deshalb muss das CO<sub>2</sub> in dem für den vorgesehenen Zweck erforderlichen Maße aufgereinigt werden.

Der Reinigungsprozess oder das Konditionieren umfasst einen Schaumabscheider, Gaswäsche mit Wasser zur Verringerung der Schwefelverbindungen, Trocknung, Geschmacksentfernung mittels Aktivkohle, Sauerstoffentzug und Komprimierung in eine Flüssigkeit zu Lagerzwecken. Dann wird es nach Bedarf dem Lagertank entnommen, wieder verdampft und in der Produktion eingesetzt.

#### Erreichbare Umweltvorteile

Weniger CO<sub>2</sub>-Emissionen auf Anlagenebene. Weniger Verbrauch fossiler Brennstoffe und Energie zur Herstellung von CO<sub>2</sub>, insbesondere zur Verwendung in der Anlage.

#### Medienübergreifende Effekte

Energieverbrauch.

#### Betriebsdaten

Im Brauereisektor beträgt die Reduktion der CO<sub>2</sub>-Emissionen mit diesem System etwa 2 kg/hl (20 kg/m<sup>3</sup>) produzierten Biers.

Aus dem Fermentationsprozess lässt sich unbehandeltes CO<sub>2</sub> mit einer Unreinheit von 20 – 1.000 ppm rückgewinnen. Die Sauerstoffkonzentration im verflüssigten CO<sub>2</sub> kann von einem Ausgangswert von 40 – 1.000 ppm auf eine Endreinheit von 5 ppm gesenkt werden. Dies wird durch das „Sauerstoffreduktionssystem“ ermöglicht<sup>8</sup>. Abbildung 4.10 zeigt die Prozessabfolge im CO<sub>2</sub>-Konditionierungssystem.

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<sup>8</sup> Anm. d. UBA-Bearb.: In den dt. Brauereien als sogenannte ORS Verfahren (Oxygen – Reduce – System) bekannt.

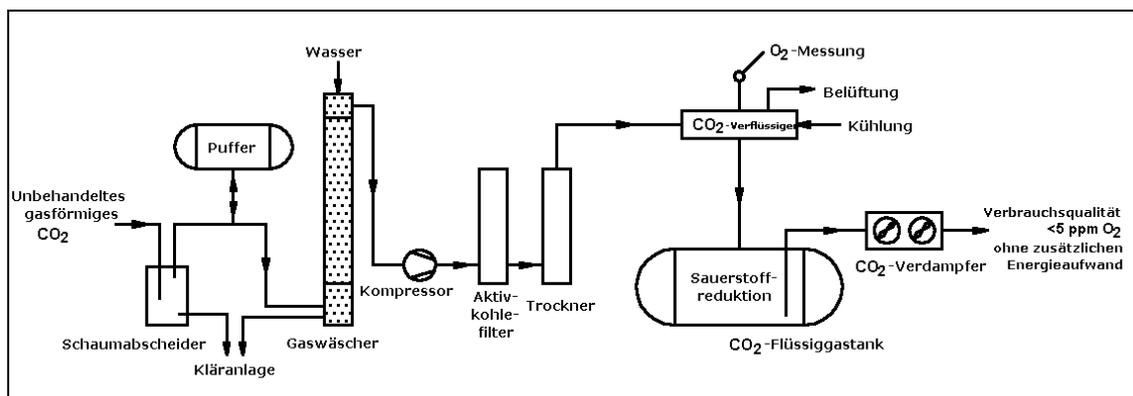


Abbildung 4.10: Prozessablaufdiagramm eines CO<sub>2</sub>-Konditionierungssystems in einer großen Brauerei

Wenn zur Kühlung der Luft- und CO<sub>2</sub>-Kompressoren ein geschlossener Wasserkühlkreislauf verwendet wird, werden Wasserverluste vermieden und das Abwasservolumen minimiert.

Die Entscheidung darüber, ob CO<sub>2</sub> angekauft wird, das in einem anderen Sektor als Koprodukt anfällt, kann anhand der verfügbaren Qualität getroffen werden.

#### Anwendbarkeit

Anwendbar in Brauereien, Weinkellereien, Brennereien und in der Produktion von Apfelwein. Das rückgewonnene CO<sub>2</sub> kann je nach Sektor folgendermaßen verwendet werden:

- zur Neutralisation von Abwasser – alle Branchen, in denen fermentiert wird
- zum Versetzen von Getränken mit Kohlensäure – Brauereiwesen, Perlwein, Apfelwein, alkoholfreie Getränke und Mineralwasser
- als Trägermedium für die Getränkeabgabe, z. B. bei Bier, Apfelwein und mit Kohlensäure versetzten alkoholfreien Getränken<sup>9</sup>
- als Gegendruckmittel in Filtriereinheiten, Tanks und Flaschen, z. B. bei Bier, Apfelwein und mit Kohlensäure versetzten alkoholischen Getränken.

#### Wirtschaftlichkeit

Industrielle Gasunternehmen können CO<sub>2</sub>, das üblicherweise ein Koprodukt aus anderen Branchen ist, kostengünstiger liefern, als es in der Anlage produziert werden könnte.

#### Anlass für die Umsetzung

Vermeidung von CO<sub>2</sub>-Emissionen und Verzicht auf den Ankauf von CO<sub>2</sub> von Dritten. Durch die Verwendung von in der eigenen Anlage rückgewonnenem CO<sub>2</sub> lässt sich das Risiko von Problemen mit Kontaminationen, Geschmack und Geruch bei CO<sub>2</sub> aus anderen Quellen vermeiden.

#### Beispielanlagen

Wird im Brauereisektor angewendet.

#### Referenzliteratur

[65, Germany, 2002, 159, CIAA-CEFS, 2003, 182, Germany, 2003, 199, Finland, 2003]

## 4.2.5 Räuchern

Unter Räuchern versteht man den Vorgang des Garens, Haltbarmachens oder Würzens von Lebensmitteln durch Kontakt mit Rauch. Es gibt zwei Arten des Räucherns. Das Heißräuchern wird üblicherweise bei 65 – 120 °C<sup>10</sup> durchgeführt und eignet sich zum vollständigen Garen von Lebensmitteln. Beim Heißräuchern wird der Rauch von brennendem oder schwelendem Holz eingesetzt. Das Kalträuchern wird üblicherweise bei 30 – 55 °C<sup>11</sup> durchgeführt und dient im Allgemeinen dazu, Lebensmittel zu konservieren oder ihnen Geschmack zu verleihen. Beim Kalträuchern werden der Rauch von schwelendem Holz, Rauchkondensate (Flüssigräuchern),

<sup>9</sup> Anm. d. UBA-Bearb.: Sicherlich ist damit der Einsatz von CO<sub>2</sub> in Schankanlagen gemeint..

<sup>10</sup> Anm. d. UBA-Bearb.: In Deutschland üblicherweise bis 80°C.

<sup>11</sup> Anm. d. UBA-Bearb.: In Deutschland überwiegend zwischen 15°C und 25°C.

Friktionsrauch oder Rauch aus überhitztem Dampf eingesetzt. Die unterschiedlichen Verfahren zur Raucherzeugung sind in den Abschnitten 4.2.5.1 bis 4.2.5.5 beschrieben.

Der VOC-Gehalt im Rauch hängt zum großen Teil von der Methode der Raucherzeugung ab. Die Methode wirkt sich auf Emissionen und damit auf die erforderliche Luftreinigung aus. Die Art des gewählten Rauchs bestimmt, welcher Geschmack erzielt wird.

Das Abgas der Räucheröfen wird mittels Verbrennung behandelt. Durch katalytische Verbrennung und Wärmerückgewinnung lässt sich der Energieverbrauch verringern.

Auf den Räucherstangen und in der Räucherkammer lagert sich Teer ab. Die Stangen werden in einer sich ständig bewegendem Trommel gereinigt, sodass die Ablagerungen durch Reibung der Stangen aneinander entfernt werden. Der Teer wird dann durch eine geregelte Wasserzufuhr (kein fließendes Wasser) entfernt. Der in Öfen oder Rinnen abgelagerte Teer wird gesammelt und als chemischer Abfall behandelt, also nicht an die Kläranlage abgegeben.

Räuchergestelle werden oft manuell mit einem Druckreiniger gereinigt. Es wird eine Waschkammer verwendet, in der das Reinigungsmittel enthaltende Wasser aufgefangen und rezirkuliert wird. Beim letzten Spülgang kann der Ablauf automatisch zur Kläranlage umgeleitet werden. Alternativ dazu kann ein Waschtunnel eingesetzt werden, in dem das Wasser aus der zweiten Stufe für die Erstspülung wiederverwendet wird.

Tabelle 4.19 zeigt die Umweltauswirkungen der verschiedenen Methoden zur Raucherzeugung.

|                         | Luftemissionen                          | Luftbehandlung       | Teer-ablagerungen  | Reinigung (Wasserverbrauch/Abwasserverschmutzung)       |
|-------------------------|---|----------------------|--------------------|---|
| <b>Brennendes Holz</b>  | Hoher VOC-Gehalt                        | erforderlich         | hoher Gehalt       | Durch Reinigung Wasserverbrauch und Abwasserentstehung  |
| <b>Schwelendes Holz</b> | Bis zu 200 chemische Bestandteile       | erforderlich         | hoher Gehalt       | Durch Reinigung Wasserverbrauch und Abwasserentstehung  |
| <b>Flüssigkeit</b>      | weitgehend verringert, z. B. Geruch/VOC | erheblich verringert | keine Ablagerungen | verringert  |
| <b>Reibung</b>          | verringert                              | unnötig              | verringert         | verringert, keine starken Reinigungsmittel erforderlich |
| <b>Überhitzer Dampf</b> | verringert                              | verringert           | verringert         | verringert  |

Tabelle 4.19: Umweltauswirkungen der verschiedenen Methoden zur Raucherzeugung

#### 4.2.5.1 Rauch von brennendem Holz

##### Beschreibung

Die Einrichtung zur Erzeugung von Rauch aus brennendem Holz besteht aus einer Kammer mit einem Rauchgenerator. Im einfachsten Betrieb werden die Produkte an Gestellen in der Kammer aufgehängt und am Boden ein Feuer aus Holzstaub oder Holzschnitzeln entzündet. Das Feuer wird so gedämpft, dass die Raucherzeugung maximiert wird und keine Flammen entstehen. Die Produkttemperatur steigt auf ungefähr 30 °C an. Die Räucherzeit kann bis zu 48 Stunden betragen.

##### Medienübergreifende Effekte

Abluft mit hohem VOC-Gehalt. Ablagerung großer Mengen Teer in der Räucherkammer.

##### Betriebsdaten

Den Angaben zufolge wird durch das Verbrennen von Sägespänen Rauch mit hohem VOC-Gehalt erzeugt. Es wird ein offenes oder halboffenes System verwendet und Luftzufuhr benötigt, d. h. es wird zusätzliche Luft verbraucht, die vor der Abgabe in die Luft gereinigt werden muss.

Wenn im Rauchgenerator Holzschnitzel verwendet werden, sind die Luftzufuhr und daher auch die Temperatur normalerweise höher. Es werden mehr Teerverbindungen gebildet, sodass ein stärkerer Reinigungsbedarf besteht. In diesem Fall ist normalerweise auch eine Rauchreinigung erforderlich.

In einer norwegischen Untersuchung wurde das Regelprogramm für den Räuchervorgang dahingehend verändert, dass der Rauchbedarf berücksichtigt wurde. Dies führte dazu, dass der Rauchgenerator schon heruntergefahren wurde, bevor das Räuchern abgeschlossen war. Der Holzschnitzelverbrauch ging dadurch ohne Änderung der Produktqualität von 8,9 kg auf 3,6 kg pro Tonne Wurst zurück.

#### Anwendbarkeit

Anwendbar in der Verarbeitung von Fisch und Fleisch.

#### Referenzliteratur

[41, Nordic Council of Ministers, 2001]

### **4.2.5.2 Rauch von schwelendem Holz**

#### Beschreibung

Rauch von schwelendem Holz besteht aus zwei Phasen, nämlich einer dispersen flüssigen Phase, z. B. Tröpfchen, und einer Dampfphase. Erstere enthält Rauchteilchen, die im Räucherprozess als unwichtig gelten. Die Dampfphase ist für die Geschmacksbildung wichtiger.

Das Räuchern kann in zwei verschiedenen Temperaturbereichen stattfinden, nämlich bei Umgebungstemperatur, bis zu 30 °C, und bei erhöhter Temperatur, zwischen 50 °C und 90 °C. Die durch schwelendes Holz erzeugte Wärme reicht nicht aus, die Temperatur auf einen Wert zwischen 50 °C und 90 °C zu erhöhen; deshalb wird zusätzliche Wärme in Form von Dampf oder durch einen Wärmetauscher zugeführt. Die Räucherdauer ist vom Produkt abhängig. Manche Produkte erfordern ein Vortrocknen oder Trocknen oder Reifen zwischen den Räucherphasen. Zur Steuerung der Produkttrocknung wird Luft verwendet, deren Temperatur und Feuchtigkeit durch Dampfrohre oder elektrische Heizgeräte eingestellt wird. Die Zeit, für die das Produkt in der Kammer verbleibt, kann von einigen Stunden bis zu mehreren Tagen reichen. Der Zeitraum, in dem das Produkt geräuchert wird, kann von 15 Minuten bis zu 4 Stunden pro Phase reichen.

#### Medienübergreifende Effekte

Die Dampfphase enthält bis zu 200 chemische Substanzen, von denen nicht alle identifiziert sind. Darunter finden sich eine Reihe organischer Säuren, Aldehyde, Ketone, Alkohole und polyzyklische Kohlenwasserstoffe. In der Räucherammer bilden sich Teerablagerungen.

#### Betriebsdaten

Angaben zufolge kann der Rauchgenerator ein kleiner Ofen sein, in dem Hartholzschnitzel oder Sägespäne langsam zu einem Bett aus bereits schwelendem Holz hinzugefügt oder auf ein elektrisch beheiztes Gitter gegeben werden. Durch den kleinen Ofen wird Luft hindurchgeführt, die den Rauch in die Räucherammer trägt, in der sich das Produkt befindet. Der die Kammer verlassende Rauch wird an die Luft abgegeben oder teilweise rückgeführt. In komplizierteren Systemen kann außerdem eine Klimaanlage integriert sein, mit der die Luft ventiliert, gekühlt, erwärmt oder befeuchtet werden kann. In älteren Typen von Kalträucheröfen wird das Sägemehl oft direkt auf dem Boden verbrannt.

#### Anwendbarkeit

Anwendbar in der Verarbeitung von Fisch, Meeresfrüchten, Fleisch, Käse, Obst und Gemüse.

#### Referenzliteratur

[41, Nordic Council of Ministers, 2001]

### **4.2.5.3 Flüssigrauch**

#### Beschreibung

Flüssigrauch wird durch Kondensation von Rauch erzeugt, an die sich zur Verringerung des Gehalts an Teer und anderen Verunreinigungen eine fraktionierte Destillation anschließt. Die entstehende Lösung wird mit Wasser verdünnt und auf das Produkt aufgesprüht. In manchen Fällen wird sie in eine Pökellake eingemischt und zu Geschmacksbildungszwecken in das Produkt injiziert.

Der Vorteil besteht darin, dass der Rauchgeschmack ohne Räuchern erzielt wird und daher die Rauchbestandteile, die als möglicherweise gesundheitsschädlich gelten, größtenteils vermieden werden. Da es keine Rauchemission gibt, verringert sich der Bedarf an Luftbehandlung erheblich.

### Erreichbare Umweltvorteile

Weniger Luftemissionen, z. B. Geruch/VOC. Bei diesem Räucherverfahren entsteht kein Teer.

### Betriebsdaten

Beim Räuchern/Garen von Wiener Würstchen sind in Dänemark bei einem Ofen mit Gaswäscher Emissionen von 2 bis 3 Millionen Geruchseinheiten, bei einem Ofen mit Flüssigrauch Emissionen in der Größenordnung von 100.000 Geruchseinheiten pro Charge (unveröffentlichte Ergebnisse, DMRI) gemessen worden. Es kann deshalb angenommen werden, dass Geruch sich durch die Verwendung von Flüssigrauch vermeiden lässt. Es muss jedoch betont werden, dass Flüssigrauch zu einem Rauchgeschmack führt, der sich von dem beim herkömmlichen Räuchern erzielten Geschmack unterscheidet, und dies wird aus Geruchs- oder Geschmacksgründen möglicherweise von den Kunden abgelehnt. Für verarbeitete Fleischprodukte ist Flüssigrauch daher nicht immer ein Mittel der Wahl.

### Anwendbarkeit

Anwendbar in der Verarbeitung von Fisch, Meeresfrüchten, Fleisch, Käse, Obst und Gemüse.

### Beispielanlagen

Wird in der Fleischverarbeitung, z. B. bei der Herstellung von Wiener Würstchen, verwendet.

### Referenzliteratur

[41, Nordic Council of Ministers, 2001]

## **4.2.5.4 Friktionsrauch**

### Beschreibung

Rauch wird durch die Reibung zwischen Holz und einem sich schnell drehenden rauen Reibrad erzeugt, wobei es zur Pyrolyse kommt. Der Rauch ist mild und enthält kaum karzinogene Substanzen. Der Prozess kann in einem geschlossenen System mit Rezirkulation durchgeführt werden, sodass eine Nachverbrennungsanlage oder anderes Rauchreinigungssystem nicht benötigt wird. Diese Methode soll eine präzisere Regulierung des erzeugten Rauchvolumens durch Änderung des Drucks zwischen Rad und Holz ermöglichen.

### Erreichbare Umweltvorteile

Geringerer Energie- und Wasserverbrauch. Geringere Verschmutzung des Abwassers. Geringere Teerzeugung.

### Betriebsdaten

Angaben zufolge beträgt die Energieeinsparung oft 50 % des Energieverbrauchs. Dadurch, dass der Rauch so mild ist, machen die Ablagerungen in der Räucherammer nur weniger als 10% der Menge aus, die sich bei der Verwendung von Rauch aus Holzschnitzeln bilden. Die Reinigung ist daher viel einfacher, und es müssen keine starken Reinigungsmittel eingesetzt werden. Es gibt weniger organische Verbindungen im Abwasser, und da die Abstände zwischen den Reinigungen länger sind, wird Wasser gespart.

### Anwendbarkeit

Anwendbar in der Verarbeitung von Fisch, Meeresfrüchten, Fleisch, Käse, Obst und Gemüse.

### Beispielanlagen

Wird in der Fischverarbeitung eingesetzt.

### Referenzliteratur

[41, Nordic Council of Ministers, 2001]

#### 4.2.5.5 Rauch aus überhitztem Dampf

##### Beschreibung

Die Pyrolyse von Holschnitzeln/-spänen kann auch dadurch erfolgen, dass überhitzter Dampf über die Holzschmitzel geleitet wird, der Rauch und Geschmack auf die Produkte überträgt. Dadurch wird die Anzahl der Substanzen im Rauch verringert, und auch der Luftüberschuss kann auf ein Minimum gesenkt werden. Da sich der überschüssige Dampf kondensieren lässt, fallen nur wenig Abgase an. Die Reinigung der Räucherammer ist ebenfalls einfacher, weil sich weniger Teerablagerungen bilden.

##### Erreichbare Umweltvorteile

Geringere Luftemissionen. Geringere Teererzeugung.

##### Anwendbarkeit

Anwendbar in der Verarbeitung von Fisch, Meeresfrüchten, Fleisch, Käse, Obst und Gemüse.

##### Referenzliteratur

[41, Nordic Council of Ministers, 2001]

#### 4.2.6 Garen

In der Nahrungsmittelproduktion stehen mehrere Gartechniken zur Verfügung, die in den Abschnitten 4.2.6.1 bis 4.2.6.6 beschrieben werden. Diese Techniken werden auch für das Garen von z. B. Fleisch und Fisch vor der Konservierung in Dosen, Flaschen und Gläsern verwendet (siehe Abschnitt 4.2.8).

##### 4.2.6.1 Wasserbadautoklav – Garwasser

##### Beschreibung

Wasserbadautoklaven ermöglichen die beste Homogenität in der Erwärmung. Dessen ungeachtet führt das Eintauchen in heißes Wasser zu Gewichtsverlusten und zur Freisetzung von Proteinen und Fett in das Wasser. Diese können abgeschöpft werden, um Nebenprodukte zurück zu gewinnen und die Kontamination des Abwassers zu vermeiden. Dadurch wird auch das Wiederverwendungspotenzial des Garwassers erhöht. Das Garwasser kann auch durch den Einsatz von Membransystemen für die Wasserreinigung öfter wiederverwendet werden.

##### Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs. Geringere Verschmutzung des Abwassers. Rückgewinnung von Nebenprodukten aus dem Garwasser.

##### Medienübergreifende Effekte

Beim Garen im Wasserbadautoklaven werden viel Wasser und Energie benötigt.

##### Betriebsdaten

Angaben zufolge können nach dem Garen von Fisch ungefähr 3 bis 4 Gramm Öl pro kg fetten Fisches in das Wasser freigesetzt werden. Nebenprodukte, z. B. Fettsäuren und Geschmacksstoffe, werden aus dem Garwasser rückgewonnen.

Beim Einsatz eines Wasserbadautoklaven zum Garen von Fleisch vor der Konservierung in Dosen entsteht Abwasser, das mit Fett, Eiweiß und Fleischstückchen verunreinigt ist.

##### Anwendbarkeit

In der Nahrungsmittelproduktion in vielen Bereichen anwendbar, z. B. für Fleisch, Fisch, Schalentiere und Gemüse.

##### Referenzliteratur

[89, Italian contribution, 2001, 134, AWARENET, 2002]

### 4.2.6.2 Wasserbadautoklav – Verwendung von Wasser statt Lake

#### Beschreibung

Durch das Garen in Wasser anstelle von Lake wird die Salinität des Abwassers verringert.

#### Erreichbare Umweltvorteile

Geringere Salinität des Abwassers.

#### Betriebsdaten

Bei manchen Rezepten kann das Garen in Lake erforderlich sein.

#### Anwendbarkeit

In der Nahrungsmittelproduktion in vielen Bereichen anwendbar, z. B. für Fleisch, Fisch, Schalentiere und Gemüse.

#### Referenzliteratur

[134, AWARENET, 2002]

### 4.2.6.3 Berieselungsautoklav

#### Beschreibung

Berieselungsautoklaven ermöglichen eine sehr gleichmäßige Erwärmung und verbrauchen weniger Wasser und Energie als Wasserbadautoklaven. Ihre Funktionsweise besteht in der gleichzeitigen Wärmewirkung von Wasser, das durch die Berieselungsvorrichtungen geführt wird, und von gesättigtem Dampf, der aus der beheizten Auffangwanne am Boden des Autoklaven aufsteigt.

#### Erreichbare Umweltvorteile

Geringerer Wasser- und Energieverbrauch als bei Wasserbadautoklaven.

#### Medienübergreifende Effekte

Energieverbrauch, z. B. zur Dampferzeugung.

#### Anwendbarkeit

In der Nahrungsmittelproduktion in vielen Bereichen anwendbar, z. B. für Fleisch, Fisch, Schalentiere und Gemüse.

#### Referenzliteratur

[134, AWARENET, 2002]

### 4.2.6.4 Dampfautoklav

#### Beschreibung

Dampfautoklaven ähneln Berieselungsautoklaven, aber sie haben keine Wassersprühvorrichtung. Die Erwärmung erfolgt durch den Dampf, der bei der Erwärmung des Wassers in der Sammelwanne entsteht. Beim Garen mit Dampf wird weniger Wasser verbraucht, es fällt weniger Abwasser an und das Abwasser ist weniger verschmutzt.

#### Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs. Weniger Abwasseraufkommen und -verschmutzung.

#### Medienübergreifende Effekte

Energieverbrauch, z. B. zur Dampferzeugung.

#### Betriebsdaten

Beim Einsatz eines Dampfautoklaven zum Garen von Fleisch und Fisch vor der Konservierung in Dosen entsteht Abwasser, das mit Fett, Eiweiß und Lebensmittelstückchen verunreinigt ist.

#### Anwendbarkeit

In der Nahrungsmittelproduktion in vielen Bereichen anwendbar, z. B. für Fleisch, Fisch, Schalentiere und Gemüse.

Referenzliteratur

[89, Italian contribution, 2001, 134, AWARENET, 2002]

**4.2.6.5 Heißluftautoklav**Beschreibung

Heißluftautoklaven verfügen über ein Rezirkulationssystem für heiße Luft, die dadurch erzeugt wird, dass Luft durch Wärmetauscher geführt wird, und einen Dampfeinlass zur Regulierung der Feuchtigkeit der Lebensmitteloberflächen. Heißluftautoklaven verteilen die Wärme gleichmäßiger als andere Autoklaven, sodass Garzeit und Gartemperatur und damit auch der Energieverbrauch gesenkt werden können.

Erreichbare Umweltvorteile

Geringerer Wasser- und Energieverbrauch.

Anwendbarkeit

In der Nahrungsmittelproduktion in vielen Bereichen anwendbar, z. B. für Fleisch, Fisch und Gemüse.

Referenzliteratur

[134, AWARENET, 2002]

**4.2.6.6 Mikrowellenautoklav**Beschreibung

In einem Mikrowellenautoklaven erfolgt die Erwärmung des Lebensmittels durch Bestrahlung mit Mikrowellen. Die dabei entstehende Wärme innerhalb des Lebensmittels ermöglicht ein schnelles Garen.

Erreichbare Umweltvorteile

Geringerer Wasser- und Energieverbrauch.

Anwendbarkeit

In der Nahrungsmittelproduktion in vielen Bereichen anwendbar, z. B. für Fleisch, Fisch, Schalentiere und Gemüse.

Referenzliteratur

[134, AWARENET, 2002, 231, Oxford University Press, 2002]

**4.2.7 Frittieren****4.2.7.1 Rezirkulation und Verbrennung von Abgasen**Beschreibung

Luftemissionen sind abhängig von der Betriebstemperatur des Frittiervorgangs. So entstehen beispielsweise beim Frittieren mit hohen Temperaturen von 180 – 200 °C schneller Ölabbauprodukte als beim Frittieren mit niedrigeren Temperaturen. Die Luft oberhalb der Fritteuse wird abgezogen und entlüftet. Diese Abluft enthält VOC, und es kann zu Beschwerden über den Geruch kommen. Durch die Rückgewinnung von Öl und Wärme und die Rückführung von Abgasen zum Brenner werden diese Emissionen minimiert.

Erreichbare Umweltvorteile

Weniger Luftemissionen, einschließlich Gerüchen. Rückgewinnung von Öl. Rückgewinnung von Energie. Rückführung von Abgasen.

Betriebsdaten

Wenn beispielsweise ein Frittiervorgang, in dem das Frittiergut knusprig ausgebacken werden soll, überwacht und abgebrochen wird, sobald der Endfeuchtigkeitsgehalt sich im kritischen Bereich von 1 % bis 2 % befindet, werden die Luftemissionen verringert. Zum Energiesparen können die Wärmetauscher außerdem in der Abzugshaube der Frittieranlage installiert werden.

Abbildung 4.11 zeigt ein Wärme- und Ölrückgewinnungssystem für eine Frittieranlage.

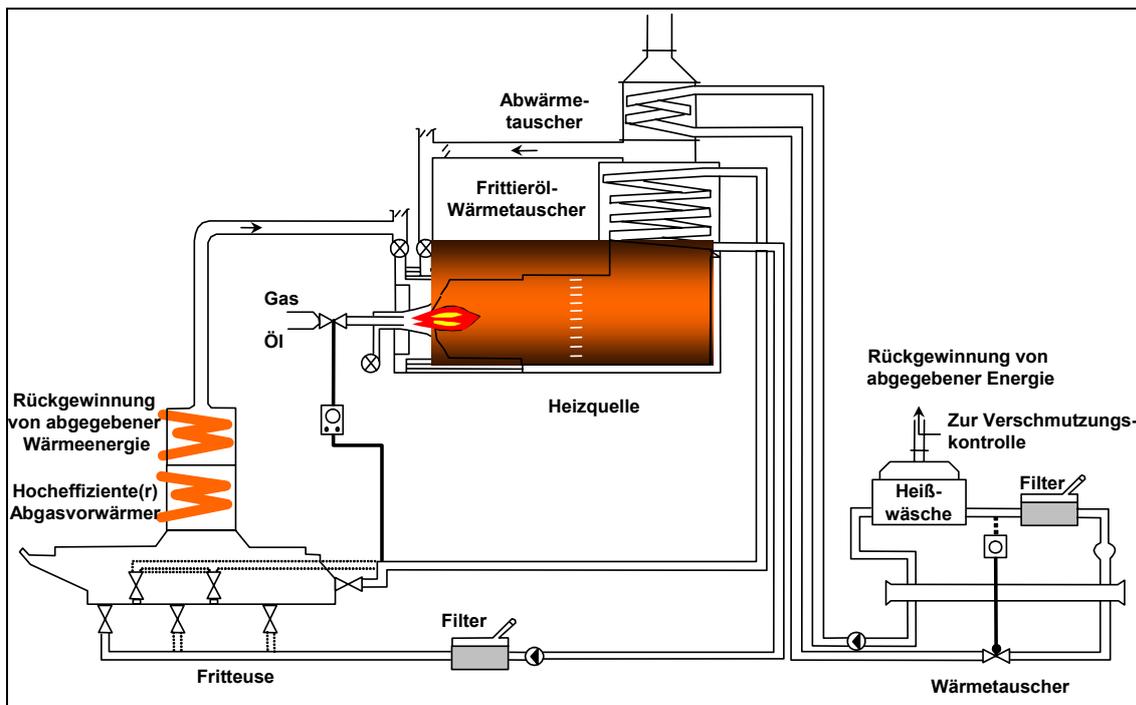


Abbildung 4.11: Rückgewinnung von Wärme und Öl: Wärmetauscher in der Abzugshaube einer Frittieranlage

Anwendbarkeit

Anwendbar in den Branchen, in denen Fisch, Fleisch, Geflügel und Kartoffeln frittiert werden.

Referenzliteratur

[85, Environment Agency of England and Wales, 2000]

**4.2.8 Konservierung in Dosen, Flaschen und Gläsern**

**4.2.8.1 Vermeiden des Garens vor dem Konservieren in Dosen, Flaschen und Gläsern, wenn die Lebensmittel während der Sterilisierung gegart werden können**

Beschreibung

Vor der Konservierung in Dosen, Flaschen und Gläsern kann das Lebensmittel gegart werden, bevor es in den Verpackungsbehälter gefüllt wird. Für dieses Vorgaren werden Wasserbad-, Berieselungs-, Dampf-, Heißluft- und Mikrowellenautoklaven (siehe Abschnitte 4.2.6 bis 4.2.6.6) verwendet. Das Vorgaren kann unterbleiben, wenn die Lebensmittel anschließend während der Sterilisierung gegart werden können (siehe Abschnitte 4.2.8.4 und 4.2.8.5).

Erreichbare Umweltvorteile

Geringerer Wasser- und Energieverbrauch. Weniger Abwasseraufkommen und -verschmutzung.

Betriebsdaten

Im Fischsektor werden mittelgroße und große Fische gegart, z. B. vor dem Einfüllen in Dosen. Kleine Fische wie Sardinen werden ganz in Dosen gefüllt und dann während der Sterilisierung in den Dosen gegart. Die Bedingungen, unter denen das Vorgaren unterbleiben und das Garen während der Sterilisation erfolgen kann, hängen von Faktoren wie der Größe der Lebensmittelstücke, der Größe von Dosen, Flaschen oder Gläsern, dem Rezept, der Qualitätssicherung für das Produkt und der Dauer des Sterilisationsvorgangs ab.

Anwendbarkeit

In vielen Bereichen der Nahrungsmittelproduktion anwendbar, und zwar bei Lebensmitteln, die gegart konserviert werden sollen.

Referenzliteratur

[134, AWARENET, 2002]

#### 4.2.8.2 Automatische Befüllung mit Rückführung übergelaufener Produkte

##### Beschreibung

Bei Lebensmitteln, die in Flüssigkeiten konserviert werden, können für Würzstoffe automatische Befüllungssysteme verwendet werden, die über eine Rückführung von übergelaufenen Flüssigkeiten, wie Sauce, Lake oder Öl, in geschlossenen Kreisläufen verfügen.

##### Erreichbare Umweltvorteile

Wenn heißes Wasser wiederverwendet werden kann, sinken Wasser- und Energieverbrauch. Geringere Abwasserverschmutzung.

##### Betriebsdaten

Beim Konservieren von Fisch in Dosen werden die Dosen mit Lake, Sauce oder Öl gefüllt. Würzflüssigkeiten können überlaufen, was, sofern sie nicht rückgewonnen werden, zu einer stärkeren Belastung des Abwassers und einer schlechten Ausnutzung von Prozessmaterialien führt. Wasserkontamination, z. B. im Sterilisator, durch übergelaufenes Material an den Dosenaußenseiten verringert die Wiederverwendungsmöglichkeiten für dieses Wasser.

##### Anwendbarkeit

In weiten Bereichen anwendbar, z. B. bei der Konservierung von Fleisch, Fisch, Krustentieren, Weichtieren und Gemüse in Dosen, Flaschen und Gläsern.

##### Anlass für die Umsetzung

Verringerung des Wasserverbrauchs und Einsparungen bei der Abwasserbehandlung.

##### Referenzliteratur

[134, AWARENET, 2002]

#### 4.2.8.3 Rückgewinnung von aufschwimmendem Öl beim Waschen gefüllter Dosen, Flaschen und Gläser

##### Beschreibung

Gefüllte Dosen, Flaschen und Gläser werden mit Wasser und Reinigungsmitteln gewaschen, um sämtliche beim Befüllen übergelaufenen Inhalte, wie Saucen, Laken oder Öl, zu entfernen. Die verbrauchte Wassermenge hängt davon ab, wie mit den Dosen, Flaschen und Gläsern verfahren wurde. Aus Reinigungsbecken lässt sich aufschwimmendes Öl rückgewinnen. Dadurch steigen die Möglichkeiten zur Wiederverwertung der Wasser-Reinigungsmittellösung, und die Verschmutzung des Abwassers wird verringert.

##### Erreichbare Umweltvorteile

Verringerung von Wasserverbrauch und Abwasseraufkommen.

##### Anwendbarkeit

Anwendbar bei der Reinigung von Dosen, Flaschen und Gläsern, die mit pflanzlichen Ölen, Fett oder Öl enthaltenden bzw. in Öl konservierten Lebensmitteln gefüllt sind.

##### Anlass für die Umsetzung

Verringerung des Wasserverbrauchs und Einsparungen bei der Abwasserbehandlung.

##### Referenzliteratur

[134, AWARENET, 2002]

#### 4.2.8.4 Chargensterilisierung nach der Befüllung von Dosen, Flaschen und Gläsern

##### Beschreibung

Die befüllten und versiegelten Dosen, Flaschen und Gläser werden in Körben in einen Sterilisator eingesetzt, z. B. in einen chargenweise betriebenen Autoklaven, und bis zu einer voreingestellten Temperatur für die erforderliche Zeitdauer erhitzt, damit eine sachgerechte Sterilisierung und Konservierung des Produkts gewährleistet ist. Manche Lebensmittel können auch während dieses Verfahrens gegart werden. Nach der Sterilisierung werden Dosen, Flaschen und Gläser mit gechlortem Wasser auf 25 - 35 °C abgekühlt.

### Erreichbare Umweltvorteile

Verringerung von Wasserverbrauch und Abwasseraufkommen.

### Medienübergreifende Effekte

Das Abwasser kann nach der Sterilisierung Spuren von Öl, Saucen und Laken enthalten, wenn die Dosen vorher nicht richtig gereinigt wurden.

### Betriebsdaten

Zu Minimierung des Wasserverbrauchs werden Autoklaven mit Wasserspeichermöglichkeit verwendet. Außerdem kann das Wasser zum Abkühlen der Dosen recirkuliert und in Reinigungsverfahren wiederverwendet werden, wenn es nicht mehr für die Sterilisierung geeignet ist.

### Anwendbarkeit

In vielen Bereichen der Nahrungsmittelproduktion anwendbar, z. B. bei der Konservierung von Fleisch, Fisch, Krustentieren, Weichtieren, Gemüse, Milch, Bier und Öl.

### Referenzliteratur

[134, AWARENET, 2002]

## **4.2.8.5 Kontinuierliche Sterilisierung nach der Befüllung von Dosen, Flaschen und Gläsern**

### Beschreibung

Kontinuierlich arbeitende Sterilisatoren ermöglichen eine genaue Regulierung der Verarbeitungsbedingungen und liefern so gleichmäßigere Produkte. Da die Druckänderungen innerhalb von Dosen, Flaschen und Gläsern allmählich erfolgen, ist die Belastung der Nähte und Ränder im Vergleich zu Chargengeräten geringer. Kontinuierlich arbeitende Sterilisatoren, z. B. Cooker-Cooler, können sich in Ausführung und Größe leicht unterscheiden und arbeiten ohne Unterbrechung. Manche Modelle haben Platz für bis zu 25.000 Dosen, Flaschen oder Gläser. Sie transportieren diese über ein Förderband durch drei Abschnitte eines Tunnels, in denen drei verschiedenen Drücke für das Vorwärmen, Sterilisieren und Abkühlen herrschen. Die Lebensmittel können während des Vorwärmens und Sterilisierens gegart werden.

### Erreichbare Umweltvorteile

Geringerer Wasser- und Energieverbrauch. Geringere Abwassermenge.

### Medienübergreifende Effekte

Das Abwasser kann nach der Sterilisierung Spuren von Öl, Saucen und Laken enthalten, wenn die Dosen, Flaschen oder Gläser vorher nicht richtig gereinigt wurden.

### Betriebsdaten

Bei der Verwendung kontinuierlich arbeitender Sterilisatoren, z. B. Cooker-Cooler, wird das Wasser laufend wiederverwendet und nach Bedarf Wasser nachgefüllt, um die minimalen Verdunstungsverluste auszugleichen. Dadurch lassen sich die verbrauchten Mengen an Wasser und Energie überwachen. Das Wasser wird für Reinigungszwecke wiederverwendet, wenn es nicht mehr für die Sterilisierung benutzt werden kann.

Die Hauptnachteile der kontinuierlichen Sterilisation sind der umfangreiche Lagerbestand im Prozess, der im Falle eines Geräteausfalls verloren wäre, und in manchen Systemen kann es zu Problemen mit Metallkorrosion und Kontamination durch thermophile Bakterien kommen, wenn keine geeigneten vorbeugenden Maßnahmen ergriffen werden.

### Anwendbarkeit

In vielen Bereichen der Nahrungsmittelproduktion anwendbar, z. B. bei der Konservierung von Fleisch, Fisch, Krustentieren, Weichtieren, Gemüse, Milch, Bier und Öl.

### Referenzliteratur

[134, AWARENET, 2002, 232, Fellows P J, ]

## 4.2.9 Verdampfung

Trocknen und Verdampfen sind oft die energieaufwendigsten Prozesse in der Nahrungsmittelproduktion. In manchen bestehenden Anlagen werden bei zahlreichen einzelnen Arbeitsgängen komplexe Kombinationen verschiedener Techniken benutzt. Verdampfung wird häufig eingesetzt, um den Feststoffgehalt von Flüssigkeiten zu erhöhen. Manchmal stellt sie einen vorbereitenden Schritt vor der Trocknung dar, die mit einer Vielzahl verschiedener Techniken erfolgen kann. Theoretisch sind für das Verdampfen von Wasser 0,611 kWh/kg (2,2 MJ/kg) erforderlich. In der Praxis hängt dieser Bedarf stark von der Verdampfungsmethode und dem Trocknertyp ab und kann von 0,556 - 0,972 kWh/kg (2,0 - 3,5 MJ/kg) betragen. Der Energieverbrauch für das Trocknen kann geringer sein, wenn der Trockensubstanzgehalt des nassen Materials höher ist. Das lässt sich durch eine Vorverdampfung oder durch spezielle Entwässerungsgeräte wie Pressen oder Zentrifugen erreichen. Dampftrockner haben einen erheblich geringeren Energieverbrauch, wenn sie mehrstufig sind (siehe Abschnitt 4.7.5.8). Manchmal werden Abgase von KWK-Verbrennungsanlagen (siehe Abschnitt 4.2.13.1.1) zum Trocknen der Produkte verwendet, wodurch der Energiebedarf sinkt.

Fallfilmverdampfer können für ein- oder mehrstufige Verdampfung verwendet werden. Es handelt sich dabei um lange röhrenförmige Strukturen aus Edelstahl. Die Flüssigkeit wird oben dem Verdampfer zugeführt und fließt in einem dünnen Film an der inneren Oberfläche beheizter Röhren oder Platten, die in dem Verdampfer angeordnet sind, nach unten. Das Prinzip der Fallfilmverdampfung ist in Abbildung 4.12 dargestellt.

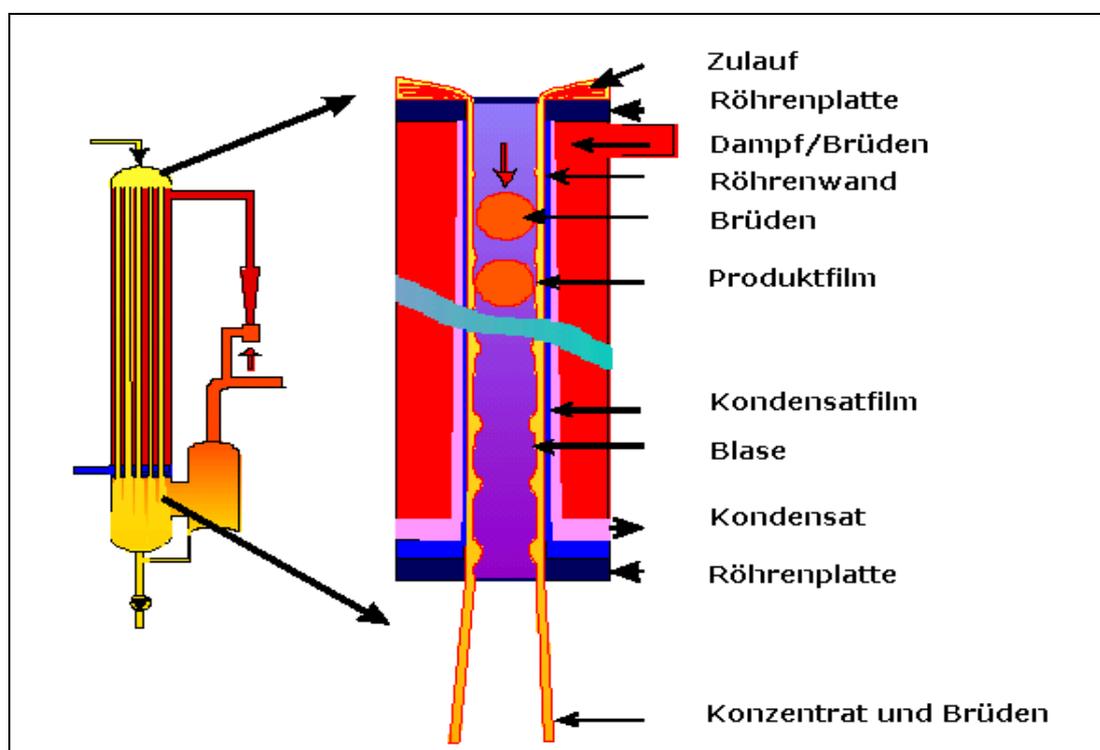


Abbildung 4.12: Prinzip der Fallfilmverdampfung  
[39, Verband der Deutschen Milchwirtschaft (German Dairy Association), 2001]

Abbildung 4.13 zeigt das Schema eines Verdampfungssystems.

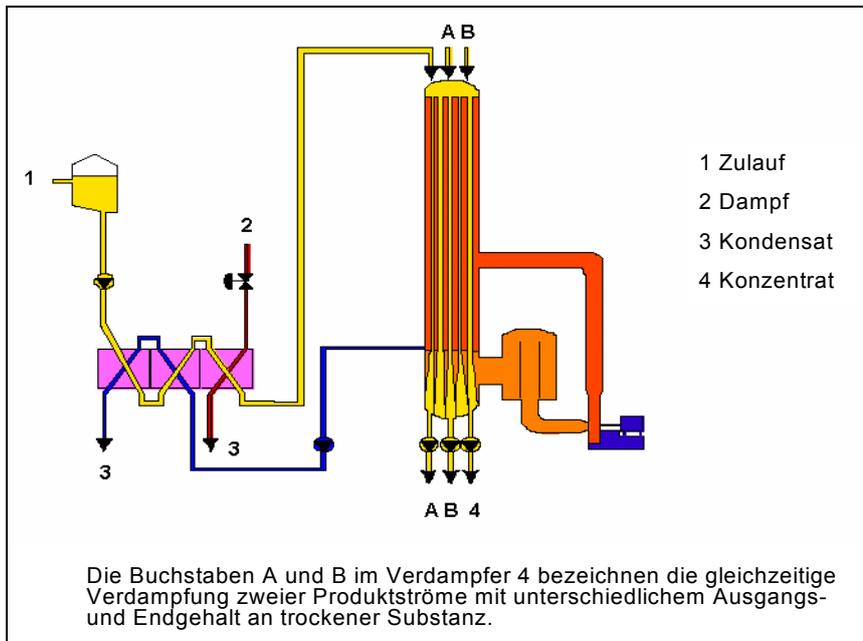


Abbildung 4.13: Milchverdampfung im Fallfilmverfahren

### 4.2.9.1 Mehrstufige Verdampfung

#### Beschreibung

Verdampfer können einzeln betrieben werden, oder die Verdampfung kann mit mehreren in Serie geschalteten Verdampfern mehrstufig erfolgen. Jeder Verdampfer wird als ein Effekt bezeichnet. Bei Mehrfacheffekt-Verdampfersystemen stellt das von einem Effekt im Verdampfer abgegebene Produkt das Zufuhrprodukt für den nächsten Effekt dar, und der Brüden mit hoher Temperatur, der aus einem Effekt des Verdampfers abgezogen wird, wird zur Erwärmung des Produkts mit niedrigerer Temperatur im nächsten Verdampfereffekt genutzt.

Die Oberflächen innerhalb des Verdampfers werden von Dampf erwärmt, der oben in den Verdampferraum injiziert wird. Dabei wird frischer Dampf oder Abgas von anderen Vorgängen verwendet, um in der ersten Stufe Wasserdampf aus der Flüssigkeit auszukochen, sodass es sich um ein Beispiel für die Rückgewinnung/Wiederverwendung von Energie handelt.

Das verdampfte Wasser hat immer noch ausreichend Energie, um als Wärmequelle für die nächste Stufe zu dienen, und so weiter. In einer Mehrfacheffektkette wird Vakuum angelegt, damit das Wasser abkochen kann. Die zu verarbeitende Flüssigkeit wird durch eine Reihe von Verdampfern geleitet, sodass sie mehreren Verdampfungsstufen unterworfen wird. Auf diese Art und Weise können mit einer Einheit Dampf, die in den ersten Verdampfer injiziert wird, drei bis sechs Einheiten Wasser aus der Flüssigkeit entfernt werden. Die Energieeinsparungen steigen mit der Zahl der Verdampfungsstufen an. Es können bis zu sieben Stufen hintereinandergeschaltet werden, aber drei bis fünf Stufen sind üblicher. Im letzten Schritt kann der Brüden durch Abkühlen mit Kühlwasser verdichtet werden. Ein Teil des Brüdens kann aus den Verdampfern abgezogen und als Wärmequelle für andere Prozessanforderungen verwendet werden.

Um die Dampfeffizienz weiter zu steigern, kann der Brüden aus jeder Verdampfungsstufe komprimiert werden (siehe Abschnitt 4.2.9.2), damit seine Energie höher ist, bevor er als Heizmedium für den nachfolgenden Verdampfer verwendet wird.

#### Erreichbare Umweltvorteile

Geringerer Energieverbrauch, z. B. durch Einleitung des Brüdens aus der ersten Stufe in die nächste Stufe des Verdampfers, in dem eine niedrigere Temperatur als in der vorhergehenden herrscht.

#### Betriebsdaten

Da die Wärme für die nächste Verdampfungsstufe genutzt wird, sparen mehrstufige Verdampfer Energie. Im Gegensatz dazu ist bei einstufigen Verdampfern keine Wärmerückgewinnung möglich.

Der Dampfbedarf für einen Einstufenverdampfer liegt bei 1,2 bis 1,4 t/t verdunstetes Wasser. Tabelle 4.20 zeigt einen Vergleich der Energieverbrauchswerte für unterschiedliche Verdampfer bei thermischer Verdichtung (TBV, siehe Abschnitt 4.2.9.2.2). Weitere Energieeinsparungen sind mit mechanischer Verdichtung (MBV, siehe Abschnitt 4.2.9.2.1) möglich, wie ebenfalls aus der Tabelle hervorgeht.

| Verdampfertyp   | Gesamtenergieverbrauch<br>(kWh/kg verdampftes Wasser) |
|-----------------|---|
| TBV, 3 Stufen   | 0,140   |
| TBV, 4 Stufen   | 0,110   |
| TBV, 5 Stufen   | 0,084   |
| TBV, 6 Stufen   | 0,073   |
| TBV, 7 Stufen   | 0,060   |
| MBV, eine Stufe | 0,015   |

**Tabelle 4.20: Vergleich der Effizienz bei Mehrfacheffektverdampfern in der Milchwirtschaft**

Angaben zufolge hat im Zuckersektor der Zuckersaft nach der Reinigung einen Feststoffgehalt von ca. 15 %, und dieser Gehalt muss erhöht werden, damit der Zucker extrahiert werden kann. Durch Verdampfung kann der Feststoffgehalt von 15 % auf über 68 % erhöht werden. Sie beruht auf dem Prinzip des Wärmetauschs zwischen dem Zuckersaft und dem in einem Kessel erzeugten Dampf. Der Wärmetausch zwischen dem Zuckersaft und dem Niederdruckdampf erfolgt in einem mehrstufigen Verdampfer. Dabei wird der aus dem Saft beim ersten Austausch entstandene Dampf wiederverwertet. In der Praxis wird der Niederdruckdampf vom Generator nach einem Wärmetausch kondensiert und zur Versorgung des Kessels rückgeführt. In demselben Austausch verdampft ein Teil des Wassers aus dem Zuckersaft, und der so erzeugte Dampf heizt den zweiten Effekt, in dem dann ein weiterer Teil des Wassers verdampft. So schließt sich ein Effekt an den anderen an. Dieser Vorgang kann bis zu sechsmal wiederholt werden. Dadurch, dass von einem Effekt zum nächsten Druck und Temperatur abnehmen, kann der Vorgang mehrere Male mit etwa derselben Energiemenge wiederholt werden.

Eine große Beispielmolkerei stellt getrocknete Produkte, frische Produkte, Schnittkäse und Butter her. Im Jahr 2000 wurden dort insgesamt etwa 321.000 Liter Milch verarbeitet, und die Gesamtproduktion von Milch- und Molkepulver belief sich auf etwa 19.000 Tonnen. In dieser Molkerei werden sowohl ein Einstufenverdampfer als auch ein fünfstufiger Fallfilmverdampfer eingesetzt. Der Einstufenverdampfer hat eine Aufnahmekapazität von 30.000 l/h; die Vorkonzentration erfolgt durch MBV, die Konzentration durch TBV. Der Fünfstufigenverdampfer hat eine Aufnahmekapazität von 22.000 l/h, und sowohl Vorkonzentration als auch Konzentration erfolgen mit TBV. Es wurden Energieeinsparungen bei Verwendung des Fünfstufigenverdampfers berichtet.

#### Anwendbarkeit

Anwendbar in der Zuckerindustrie, in der Stärkeverarbeitung, beim Aufkonzentrieren von Tomaten-, Apfel- und Zitrus-saft sowie bei der Verdampfung von Milch und Molke.

#### Referenzliteratur

[39, Verband der Deutschen Milchwirtschaft (German Dairy Association), 2001, 61, CEFS, 2001, 65, Germany, 2002]

### **4.2.9.2 Brüdenverdichtung**

Durch die Verdichtung von Brüden kann der Energiebedarf von Konzentrationsprozessen in der Nahrungsmittelproduktion deutlich gesenkt werden. So wird beispielsweise bei der Würzekochung in Brauereien Wasserdampf abgegeben. Die Wärme, die zum Verdampfen des Wassers und zum Konzentrieren der Lösung eingesetzt wird, kann durch Kondensation des abgegebenen Dampfes (Brüden) rückgewonnen werden. Gängige Arten von Verdichtern sind Rotationsverdichter, Schneckenverdichter, Radialstrom-Turboverdichter und Gebläse.

Damit die im Brüden gespeicherte Kondensationswärme genutzt werden kann, um zusätzliche Wärme für den Konzentrationsprozess zu liefern, muss die Brüdenverdichtung bei einer Temperatur oberhalb des Siedepunkts stattfinden. Zur Erhöhung der Kondensationstemperatur wird der Brüden um 0,1 - 0,5 bar (0,1 - 0,5 hPa) verdichtet. Dann wird die Kondensationswärme des verdichteten Brüdens über einen Wärmetauscher zur Konzentrationseinheit zurückgeführt.

Abgesehen vom Energiebedarf des Verdichters ist keine weitere Energiezufuhr erforderlich. Das Verhältnis von rückgewonnener zu aufgewendeter Energie, also die Leistungszahl, kann bis zu 40 betragen. Neben der Energieeinsparung und Verringerung der Energiekosten ist die Verringerung von Geruchsemissionen ein weiterer wichtiger Grund für die Brüdenverdichtung.

Ob die Installation von Brüdenverdichtungstechniken möglich ist, hängt zum großen Teil von den Investitionskosten und der Amortisation durch geringere Betriebskosten ab. Unterschiedliche und sich ändernde Energiekosten in den verschiedenen Ländern können ebenfalls Einfluss auf die Entscheidung haben. In manchen Branchen erfolgt der Betrieb saisonal, z. B. 50 Tage lang für die Verarbeitung von Tomaten, sodass auch die Länge der Einsatzdauer ein wichtiger Faktor ist.

#### 4.2.9.2.1 Mechanische Brüdenverdichtung (MBV)

##### Beschreibung

Der verdampfte Brüden wird durch einen mechanischen Verdichter komprimiert und als Wärmequelle wiederverwendet. Die latente Wärme ist größer als die Stromzufuhr zum Verdichter, also ist eine große Leistungszahl (COP) verfügbar. Bei der MBV wird der gesamte Brüden verdichtet, sodass ein hoher Grad an Wärmerückgewinnung erzielt wird. Das System wird mit elektrischem Strom betrieben, benötigt aber einen dampfbeheizten Schlussverdichter, um hohe Temperaturen zu erreichen. Es kommen zwei Verdichterarten zum Einsatz, nämlich ein Gebläse und eine Hochgeschwindigkeitsturbine. In der Praxis ist das Gebläse der am weitesten verbreitete Verdichtertyp, da es über die bessere Energieeffizienz verfügt. Das Schema eines MBV-Betriebs ist in Abbildung 4.14 dargestellt.

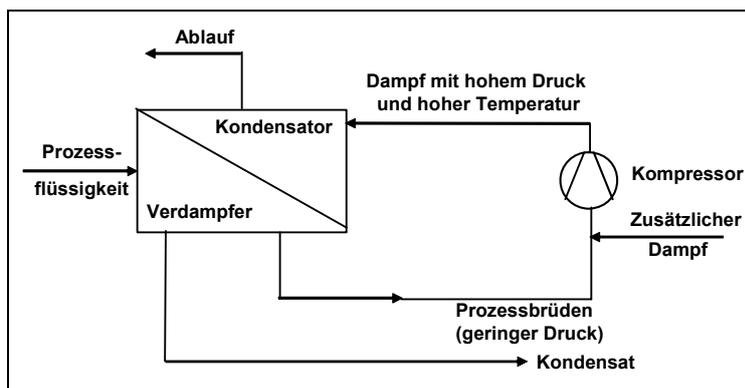


Abbildung 4.14: Prinzip der MBV

##### Erreichbare Umweltvorteile

Verringerte Geruchsemissionen. Geringerer Energieverbrauch als bei der TBV (siehe Abschnitt 4.2.9.2.2). Geringerer Reinigungsbedarf, da weniger verbranntes Produkt abgelagert wird.

##### Medienübergreifende Effekte

Zum Betrieb des Brüdenverdichters ist Strom erforderlich. Die MBV ist laut, sodass eine Lärmisolierung benötigt wird.

##### Betriebsdaten

Angaben zufolge beträgt der Energieverbrauch eines MBV-Verdampfers etwa 10 kWh/t verdampftes Wasser, bei vernachlässigbarem Stromverbrauch. Da der gesamte Brüden, nicht nur ein Teil davon wie bei der TBV, verdichtet wird, wird ein höherer Grad an Wärmerückgewinnung erzielt. Außerdem reicht eine geringere Verdampfungstemperatur aus, was weniger Produktverbrennung bedeutet. Tabelle 4.20 zeigt, dass mit der MBV höhere Energieeinsparungen möglich sind als mit der TBV.

Eine japanische Beispielmolkerei hat für ihren Milchpulverprozess einen vierstufigen MBV-Verdampfer als Ersatz für den vorhandenen vierstufigen TBV-Verdampfer installiert. Bei der Implementation des MBV-Systems musste die vorgesehene Verdampfungskapazität aufrechterhalten und gleichzeitig ein Verbrennen der Milch vermieden werden, wodurch die Oberflächen der Wärmetauscherröhren im Verdampfer verunreinigt worden wären. Ein Fallfilmverdampfer und ein automatisches Regelsystem zur Regulierung von Betriebsparametern wie Durchflussrate, Temperatur und Druck wurden installiert. Die MBV wird seither erfolgreich mit



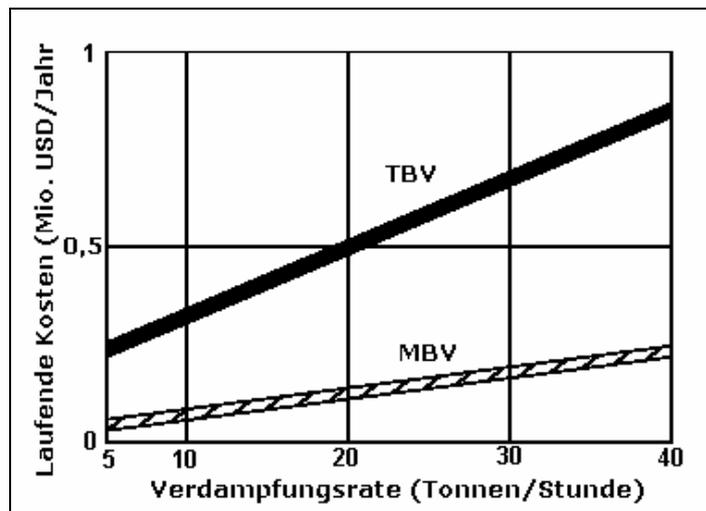


Abbildung 4.16: Vergleich der Betriebskosten für TBV- und MBV-Verdampfer

In der japanischen Beispielmolkerei betragen die Kosten für den neuen MBV-Verdampfer 1,5 Millionen EUR, während ein neuer TBV-Verdampfer 1,3 Millionen EUR gekostet hätte. Bei einer Verdampfungsrate von 30 t/h betragen die jährlichen Betriebskosten des MBV-Verdampfers 175.000 EUR im Vergleich zu den früheren jährlichen Betriebskosten von 680.000 EUR für den TBV-Verdampfer, was einer Einsparung von fast 75 % entspricht.

Beispielanlagen

Molkereien in Japan und Finnland und eine große Brauerei in Deutschland.

Referenzliteratur

[39, Verband der Deutschen Milchwirtschaft (German Dairy Association), 2001, 42, Nordic Council of Ministers, et al., 2001, 65, Germany, 2002, 70, UNEP, et al., 2000, 128, CADDET Energy Efficiency, 1992]

**4.2.9.2.2 Thermische Brüdenverdichtung (TBV)**

Beschreibung

Bei der TBV wird der Brüden durch Verdichter mit Dampf injektion verdichtet. Diese Verdichter können feste oder variable Injektionsdüsen haben. Die für die Verdichtung benötigte thermische Energie wird als Frischdampf von einem Kessel bereitgestellt.

Der Frischdampf passiert die Injektionsdüse und wird auf das Druckniveau des empfangenden Brüdens reduziert. Durch den Unterschied in der Geschwindigkeit wird der Brüden eingetragen. Brüden und Frischdampf werden in der Mischkammer gemischt. Durch Änderungen der Durchflussöffnung des Diffusors wird der Druck geregelt, mit dem der gemischte Dampf den Verdichter verlässt.

Erreichbare Umweltvorteile

Verringerte Geruchsemissionen.

Medienübergreifende Effekte

Höherer Energieverbrauch als bei der MBV.

Betriebsdaten

Im Vergleich zur MBV hat die TBV die Vorteile, ohne bewegliche Teile auszukommen und zuverlässiger zu arbeiten. Angaben zufolge ermöglicht die TBV lange Produktionszyklen und eine Verringerung der Reinigungshäufigkeit.

Anwendbarkeit

Anwendbar in der Zuckerindustrie, in der Stärkeverarbeitung, beim Aufkonzentrieren von Tomaten-, Apfel- und Zitrus-saft, in Brauereien sowie bei der Verdampfung von Milch und Molke.

Wirtschaftlichkeit

Geringere Anschaffungs-, aber höhere Betriebskosten als die MBV.

Referenzliteratur

[39, Verband der Deutschen Milchwirtschaft (German Dairy Association), 2001, 65, Germany, 2002, 128, CADDET Energy Efficiency, 1992]

## 4.2.10 Kühlung

Weitere Informationen über Kühlung sind im „BVT-Merkblatt zur Kühlung“ zu finden [67, EC, 2001].

### 4.2.10.1 Einsatz eines Plattenwärmetauschers für das Vorkühlen von Eiswasser mit Ammoniak

Beschreibung

Eiswasser wird als Kühlmedium beispielsweise für das Kühlen von Milch und Gemüse verwendet. Die Energiemenge, die für die Herstellung von Eiswasser verbraucht wird, kann durch den Einbau eines Plattenwärmetauschers reduziert werden, in dem das rückgeführte Eiswasser mit Ammoniak vorgekühlt wird, bevor die abschließende Kühlung in einem Eiswassersammeltank mit einem Röhrenverdampfer stattfindet. Das liegt daran, dass die Verdampfungstemperatur von Ammoniak in einem Plattenkühler höher ist als bei der Verwendung von Verdampferrohren, nämlich bei  $-1,5\text{ °C}$  anstatt  $-11,5\text{ °C}$ .

Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

Medienübergreifende Effekte

Die Benutzung von Ammoniak birgt Sicherheitsrisiken. Leckagen können vermieden werden, wenn Planung, Betrieb und Wartung fachgerecht durchgeführt werden.

Betriebsdaten

Den Angaben zufolge kann die Kapazität eines bestehenden Eiswassersystems erhöht werden, ohne dass die Kompressorkapazität erhöht werden muss, wenn ein Plattenkühler für das Vorkühlen des rückgeführten Eiswassers installiert wird.

In einer Beispielmolkerei wurden durch Einbau dieses Vorkühlsystems in ein bestehendes Eiswassersystem fast 20 % des Stroms eingespart.

Anwendbarkeit

Dieses Kühlsystem wird häufig in neuen Anlagen eingesetzt, kann aber auch in bestehenden Anlagen angewendet werden.

Wirtschaftlichkeit

Die Kosten sind abhängig vom bestehenden Eiswassersystem und dessen Kapazität. In einer Beispielmolkerei wurden die Investitionskosten auf etwa 50.000 EUR einschließlich Plattenkühler, Pumpe, Ventilen, Regulatoren, Rohren und Installationsarbeiten geschätzt.

Anlass für die Umsetzung

Geringerer Verbrauch elektrischer Energie und/oder erhöhte Kühlkapazität ohne Investitionskosten für ein neues Eiswasserbecken.

Beispielanlagen

Eine Molkerei in Schweden.

Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001]

### 4.2.10.2 Vorkühlung von Eiswasser mit kaltem Wasser aus einem Fluss oder See

#### Beschreibung

Eiswasser wird als Kühlmedium beispielsweise für das Kühlen von Milch und Gemüse verwendet. Kaltes Wasser aus einem Fluss oder See kann zur Vorkühlung von Eiswasser verwendet werden.

#### Erreichbare Umweltvorteile

Der Verbrauch an elektrischer Energie wird, je nach Temperatur des Flusswassers, in einem gewissen Grad gesenkt.

#### Medienübergreifende Effekte

Es wird Energie für das Pumpen des Wassers zum Kühlturm benötigt. Das Flusswasser wird unverschmutzt, aber mit leicht erhöhter Temperatur zurückgeführt.

#### Betriebsdaten

In einer Beispielmolkerei wird kaltes Flusswasser in einen Kühlturm gepumpt, wo das warme Wasser eines geschlossenen Eiswassersystems vor der abschließenden Kühlung in einem Eiswassertank vorgekühlt wird. Das Flusswasser wird dann in den Fluss zurückgeführt. Das System spart Kühlenenergie, die einer Temperaturabsenkung um 7 – 10 °C entspricht.

#### Anwendbarkeit

Anwendbar, wenn die Anlage in der Nähe eines kaltes Wasser führenden Flusses liegt.

#### Wirtschaftlichkeit

Das System erfordert Rohrleitungen vom Fluss und zurück sowie ein effizientes Pumpsystem und einen Vorratstank. Eine Beispielmolkerei gab Investitionskosten in Höhe von etwa 230.000 EUR und jährliche Einsparungen von etwa 23.000 EUR an.

#### Anlass für die Umsetzung

Geringere Energiekosten.

#### Beispielanlagen

Eine Molkerei in Schweden.

#### Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001]

### 4.2.10.3 Geschlossener Kühlkreislauf

#### Beschreibung

Wasser wird zur Kühlung beispielsweise eines Pasteurisators oder Fermenters verwendet. Das Wasser wird über einen Kühlturm oder einen an eine zentrale Kühlanlage angeschlossenen Kühler rezirkuliert, d. h., es wird erneut gekühlt und zu dem zu kühlenden Gerät zurückgeleitet. Wenn Algen- oder Bakterienwachstum unterbunden werden muss, können dem umlaufenden Wasser Chemikalien zugesetzt werden. Andernfalls kann das Kühlwasser zu Reinigungszwecken weiterverwendet werden.

#### Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs und weniger Abwasserbehandlung.

#### Medienübergreifende Effekte

Zum Kühlen des Kühlwassers wird möglicherweise Energie verbraucht. Es ist unter Umständen möglich, etwas von dieser Wärme rückzugewinnen.

#### Betriebsdaten

Angaben zufolge können mit geschlossener Kühlung gegenüber einem offenen System 80 % des Wasserverbrauchs eingespart werden. In Gegenden, in denen Wasser knapp ist, kann dies von Bedeutung sein. Durchlaufkühlwasser, das nicht mit den Nahrungsmittelmaterialein in Berührung kommt, kann keine Kontaminationen einschleppen und kommt für die direkte Abgabe in Gewässer in Frage; allerdings ist es thermisch belastet. Wenn nicht kontaminiertes Durchlaufkühlwasser durch eine Kläranlage geleitet wird, so

steigt der Energieverbrauch und es findet eine Verdünnung statt, ohne dass die Gesamtbelastung abnimmt; deshalb ist die direkte Einleitung in ein Gewässer vorteilhaft.

In rezirkulierenden Kühlturmsystemen wird das Kühlwasser ständig durch einen Kühlturm rückgeführt. Durch die Zirkulation des Wassers über den Kühlturm wird jedoch eine hohe Konzentration gelösten Sauerstoffs aufrechterhalten, die zu Korrosion innerhalb des Systems führen kann, und Verdampfung von Wasser im Turm kann zu einer Anreicherung von Schwebstoffen führen. Das rezirkulierende Wasser kann daher eine Behandlung zur Korrosionsprävention erfordern, und ein Teil des Wassers muss regelmäßig abgelassen werden, damit die Anreicherung übermäßiger Mengen gelöster Feststoffe verhindert wird. Außerdem müssen Vorsichtsmaßnahmen gegen das Wachstum von Legionellen ergriffen werden, damit das Spritzwasser von Kühltürmen nicht zu einem möglichen Herd der Legionärskrankheit wird. Geschlossene Systeme minimieren die Korrosion und es gibt keine Anreicherung gelöster Feststoffe.

Wenn eine reiche Wasserquelle, wie beispielsweise ein Fluss mit großer Wasserführung, verfügbar ist, können die medienübergreifenden Effekte, die mit dem Kühlen in geschlossenen Systemen einhergehen, größer sein. Wenn der Fluss das erforderliche Volumen liefert und die thermische Belastung ohne wesentliche Beeinträchtigung der aquatischen Lebensgemeinschaft und ohne Störung anderer Nutzer, die Oberflächenwasser verwenden, aufnehmen kann, und wenn das Wasser nicht verschmutzt wird, kann die Durchlaufkühlung aus Umweltsicht die bessere Lösung darstellen. Für Durchlaufkühlwasser wird auch Energie benötigt, um es von der Entnahme zur Anlage und wieder aus der Anlage herauszupumpen. Wenn nicht darauf geachtet wird, Leckagen im gekühlten System zu vermeiden, kann es zur Abgabe von kontaminiertem Wasser kommen.

In einer Beispielbrauerei mit einer Kapazität von 500.000 hl/Jahr wurde in einer Tunnelpasteurisationsanlage als Ersatz für ein mit Frischwasser betriebenes offenes Kühlsystem ein geschlossenes Kühlsystem installiert. Der Rückgang des Wasserverbrauchs wurde auf 50.000 m<sup>3</sup>/Jahr geschätzt.

Es wird berichtet, dass bei der Kühlung von Fermentern die geschlossene Kühlung mit einer Kühlanlage und einer Umwälzpumpe zu einer besseren Kühlung führt.

In der Zuckerproduktion wird Kühlwasser am Standort für die Stromerzeugung mit Turbinen verwendet. Normalerweise wird das Kühlwasser von einem Fluss abgezogen und passiert eine Turbine einmal, bevor es in den Fluss zurückgeleitet wird.

#### Anwendbarkeit

Anwendbar in Molkereien, Brauereien, der Herstellung alkoholfreier Getränke und der Zuckerproduktion aus Zuckerrüben.

#### Wirtschaftlichkeit

Bei einem Fermenter wurden die potenziellen Kosten als mittelmäßig, die Amortisationsdauer aber als kurz angegeben.

Im oben genannten Brauereibeispiel betragen die Investitionskosten für die Installation des Kühlturms und anderer notwendiger Ausrüstungen 45.000 USD (vor 1996), und die Amortisationsdauer betrug etwa ein Jahr.

#### Anlass für die Umsetzung

Geringerer Wasserverbrauch, dadurch geringeres Abwasseraufkommen und entsprechende finanzielle Einsparungen.

#### Referenzliteratur

[13, Environment Agency of England and Wales, 2000, 23, Envirowise (UK) and Dames & Moore Ltd, 1998, 59, Danbrew Ltd., 1996, 222, CIAA-Federalimentare, 2003, 223, Italy M. Frey, 2003]

### **4.2.11 Tiefkühlung**

Siehe 4.2.15 für verwandte Techniken beim Kühlen.

### 4.2.11.1 Energieeffizienz beim Tiefkühlen

Die größten Energieeinsparungen lassen sich beim Kühlen und Tiefkühlen erzielen. Einsparungen werden möglich durch die richtige Einstellung der Betriebsparameter, wie beispielsweise der Verdampfer Temperatur, der Förderbandgeschwindigkeit und der Gebläseleistung im Gefriertunnel. Diese hängen vom verarbeiteten Produkt und vom Durchsatz ab. Der Energieverbrauch elektrischer Systeme im Gefriertunnel kann so gering wie möglich gehalten werden, wenn Frequenzwandler (siehe Abschnitt 4.2.13.9) an den Gebläsen und dem Verteilerband eingebaut werden und eine hocheffiziente, energiesparende Beleuchtung gewählt wird.

### 4.2.11.2 Reduzierung des Kondensationsdrucks

#### Beschreibung

Die Effizienz oder die Leistungszahl des Gefriergeräts wird hauptsächlich vom Verdampferdruck und vom Kondensationsdruck bestimmt. Durch die Senkung des Kondensationsdrucks wird die Leistungszahl erhöht und der Stromverbrauch gesenkt. Der Kondensationsdruck wird durch Bereitstellung ausreichender Kondensationsgeräte so niedrig wie möglich gehalten.

#### Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

#### Anwendbarkeit

Wird in der Tiefkühlung und Kühlung verpackter und unverpackter Lebensmittelprodukte eingesetzt.

#### Referenzliteratur

[31, VITO, et al., 2001, 32, Van Bael J., 1998]

### 4.2.11.3 Reduzierung der Kondensationstemperatur

#### Beschreibung

Durch die Senkung der Kondensationstemperatur wird die Leistungszahl erhöht und der Stromverbrauch gesenkt. Diese Absenkung lässt sich durch die Ausstattung mit einer angemessenen Kapazität an Kondensatorbatterien erzielen, sodass selbst im Sommer, der die Hochsaison im Gemüsesektor darstellt, hinreichend niedrige Kondensationstemperaturen erreicht werden können.

Geringe Temperaturen lassen sich auch erzielen, indem die Kondensatoren saubergehalten und stark korrodierte Geräte ersetzt werden. Blockierte Kondensatoren bewirken einen Anstieg der Kondensationstemperatur, und die Kühlkapazität sinkt, sodass die erforderliche Temperatur möglicherweise nicht erreicht wird.

Ein Beitrag zur Senkung der Kondensationstemperatur kann auch dadurch geleistet werden, dass darauf geachtet wird, dass die Luft, die in den Kondensator eintritt, eine möglichst niedrige Temperatur hat. Je wärmer die in den Kondensator eintretende Luft ist, desto höher ist die Kondensationstemperatur. Minimieren lässt sich der Eintritt warmer Luft bei Bedarf durch Beschattung der Kondensatoren, Vermeidung einer Umwälzung warmer Luft, Beseitigung sämtlicher Behinderungen im Luftstrom sowie durch das Tiefkühlen bei Nacht.

#### Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

#### Betriebsdaten

Durch das Absenken der Kondensationstemperatur um 1 °C wird die Leistungszahl um 2 % erhöht. Durch das Absenken der Kondensationstemperatur um 5 °C wird der Stromverbrauch um 10 % gesenkt.

#### Anwendbarkeit

Wird in der Tiefkühlung und Kühlung verpackter und unverpackter Lebensmittelprodukte eingesetzt.

#### Referenzliteratur

[32, Van Bael J., 1998, 69, Environment Agency of England and Wales, 2001]

#### 4.2.11.4 Erhöhung der Verdampfungstemperatur

##### Beschreibung

Durch das Anheben der Verdampfungstemperatur wird die Energieleistung verbessert. Zu diesem Zweck kann eine gleichzeitige Optimierung verschiedener Gefriertunnel, wie in Abbildung 4.17 dargestellt, durchgeführt werden. Diese Optimierung muss jeweils erneut durchgeführt werden, wenn ein Tunnel außer Betrieb genommen, ein anderes Produkt verarbeitet oder eine andere Durchflussrate eingestellt wird.

##### Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

##### Betriebsdaten

Angaben zufolge steigt bei einer Anhebung der Verdampferstemperatur um 1 °C die Leistungszahl um 4 % und die Kühlkapazität um 6 %.

Eine flämische Studie zum Energieverbrauch beim Tiefkühlen von Gemüse in einem Gefriertunnel hat ergeben, dass sich die größten Einsparungen erzielen lassen, wenn die Verdampferstemperatur, die Verweildauer des Gemüses im Gefriertunnel und die Luftstromraten an den Gemüsedurchsatz und die Art des Gemüses angepasst werden. Diese Studie zeigt, dass es nicht immer nötig ist, die Verdampferstemperatur auf die niedrigste Stufe, also auf -40 °C einzustellen, um eine gute Tiefkühlqualität zu erzielen. Außerdem ist es sehr wichtig, die Temperatur des Produkts nach dem Durchlaufen des Gefriertunnels zu überwachen. Sehr niedrige Temperaturen, also unterhalb von -18 °C, sind nicht erforderlich, da das Gemüse letztlich in einem abgeschlossenen Raum bei -18 °C gelagert wird. Hohe Temperaturen, also oberhalb von -16 °C, können zu einer verminderten Tiefkühlqualität führen. Im schlimmsten Fall könnte die gesamte Masse während der Lagerung in Kisten zusammenfrieren. Die Schlussfolgerungen aus der Studie sind in Abbildung 4.17 zusammengefasst.

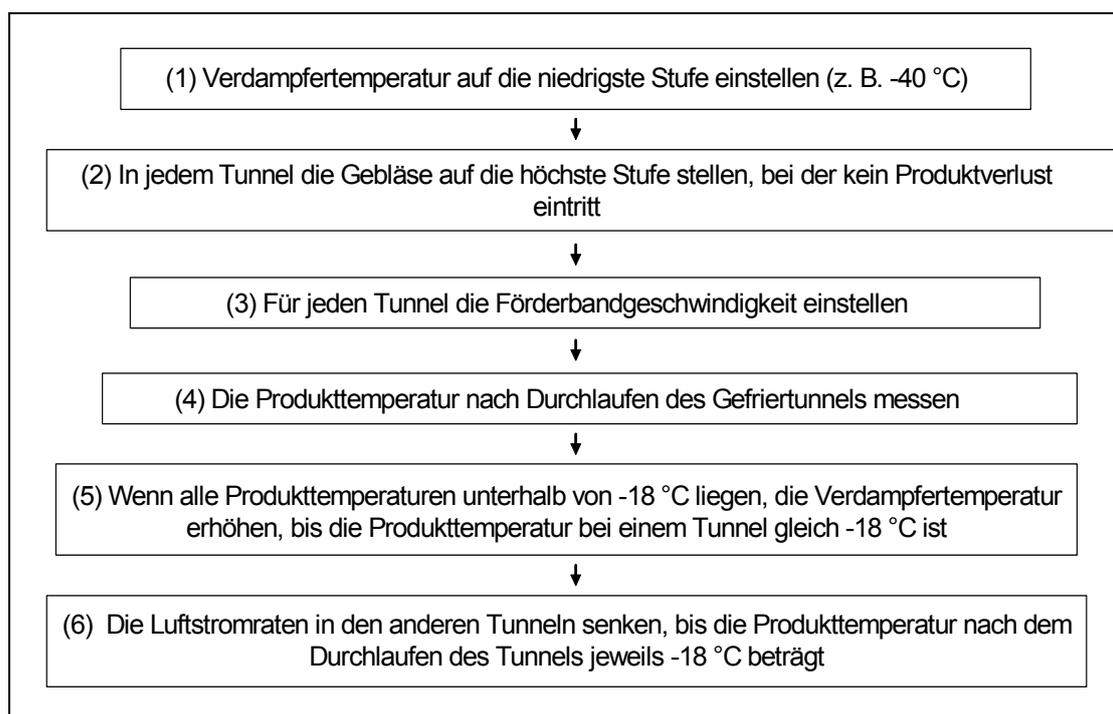


Abbildung 4.17: Optimierung der Gefriertunnel bei der Produktion von Tiefkühlgemüse

Anmerkungen zu Abbildung 4.17:

- 1) Die Verdampferstemperatur der Gefriereinheit wird auf die niedrigste Position eingestellt, z. B. -40 °C.
- 2) Die Gebläse werden auf die maximale Luftstromrate eingestellt, die ohne Produktverlust betrieben werden kann. Wenn die Luftstromventile ganz geöffnet sind bzw. die höchste Umdrehungszahl eingestellt ist, werden Produktteile aus dem Bett geblasen. Dann werden die Ventile weiter geschlossen bzw. die Umdrehungszahl gesenkt.

- 3) Beim Anpassen der Förderbandgeschwindigkeit, die umgekehrt proportional zur Verweildauer auf dem Band ist, wird sorgfältig darauf geachtet, dass die Schichtdicke nicht zu gering ist, da dies immer zur Bildung besser durchströmter Luftkanäle im Gemüsebett führt, was bedeutet, dass der Rest des Bettes nur von wenig Luft erreicht wird. Die Schichtdicke darf auch nicht zu hoch eingestellt sein, weil sonst die unteren Schichten nicht tiefgekühlt werden. Wenn der Druckabfall über dem Gemüsebett ansteigt, sinkt die Luftgeschwindigkeit und es wird weniger Wärme abgeführt.
- 4) Die Produkttemperatur wird in jedem Gefriertunnel gemessen. Für diese Messung wird ein isolierter Behälter mit dem Produkt gefüllt. Die Ablesung erfolgt, sobald sich die Temperatur stabilisiert hat. Unmittelbar nach dem Einfrieren ist die Außentemperatur geringer als die Temperatur im Inneren.
- 5) Wenn die Produkttemperatur für alle Tunnel unterhalb von  $-18\text{ °C}$  liegt, wird die Verdampfer-temperatur höher eingestellt. Das wird so lange wiederholt, bis die Produkttemperatur in einem der Gefriertunnel gleich  $-18\text{ °C}$  ist. Wenn in einem der Tunnel die Produkttemperatur bei niedrigster Verdampfer-einstellung über  $-18\text{ °C}$  liegt, wird der Gemüsedurchsatz des betreffenden Tunnels gesenkt.
- 6) In den anderen Gefriertunneln wird die Luftstromrate gesenkt, wenn eine Produkttemperatur von  $-18\text{ °C}$  erreicht wird.

### Anwendbarkeit

Anwendbar beim Tiefkühlen verpackter und unverpackter Lebensmittelprodukte.

### Referenzliteratur

[31, VITO, et al., 2001, 32, Van Bael J., 1998]

#### **4.2.11.5 Verwendung hocheffizienter Motoren zum Antrieb von Gebläsen**

##### Beschreibung

Die Gebläsemotoren werden im Gefriertunnel installiert. Die für die Motoren gelieferte elektrische Energie muss daher von der Gefriereinheit abgeleitet werden. Durch den Einsatz hocheffizienter Motoren zum Antrieb der Gebläse kommt es daher nicht nur zu einer direkten Stromeinsparung, z. B. durch den geringeren Verbrauch der Gebläse, sondern auch zu einer indirekten Einsparung, beispielsweise durch die geringere Kühllast für die Gefriereinheit.

##### Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

##### Anwendbarkeit

Angewendet beim Tiefkühlen verpackter und unverpackter Lebensmittelprodukte.

##### Referenzliteratur

[31, VITO, et al., 2001, 32, Van Bael J., 1998]

#### **4.2.11.6 Verringerung der Gebläseleistung während kurzer Produktionspausen**

##### Beschreibung

Beim Tiefkühlen von Lebensmitteln kommt es regelmäßig zu Problemen bei der Zufuhr zum Tiefkühlgerät in einem Verarbeitungsschritt oder bei der Umstellung von einem Produkt auf ein anderes. Während dieser Zeiträume ist es dennoch wichtig, den leeren Gefriertunnel auf einer hinreichend niedrigen Innentemperatur zu halten. Deswegen müssen zwar die Gebläse weiterlaufen, aber die Luftstromraten können reduziert werden. Dazu können Motoren mit regulierbarer Umdrehungszahl auf die niedrigste Frequenz geschaltet werden. Außerdem kann eine Reihe von Gebläsen ausgeschaltet werden. Dadurch wird der Energieverbrauch von Gebläsen und Kühleinheit gesenkt.

##### Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

##### Betriebsdaten

Jede Verringerung der Gebläseleistung um  $1\text{ kW}_e$  führt zu einer Gesamteinsparung von  $1,4$  bis  $1,6\text{ kW}_e$ .

##### Anwendbarkeit

Angewendet beim Tiefkühlen verpackter und unverpackter Lebensmittelprodukte.

Referenzliteratur

[31, VITO, et al., 2001, 32, Van Bael J., 1998]

**4.2.11.7 Betrieb ohne automatisches Abtauen während kurzer Produktionspausen**Beschreibung

Beim Tiefkühlen von Lebensmitteln kommt es regelmäßig zu Problemen bei der Zufuhr zum Tiefkühlgerät in einem Verarbeitungsschritt oder bei der Umstellung von einem Produkt auf ein anderes. Während dieser Zeiträume ist es dennoch wichtig, den leeren Gefriertunnel auf einer hinreichend niedrigen Innentemperatur zu halten. Um den Energieverbrauch während dieser Pausen zu senken, kann die Abtauautomatik der Verdampfer ausgeschaltet werden, da in einem leeren Gefriertunnel nur wenig oder gar keine Feuchtigkeit oder Wasser transportiert wird; Wasser z. B. wird nur beim Ein- und Austritt von Lebensmitteln mittransportiert. Dadurch wird das erneute Abkühlen des Verdampfers nach dem Abtauen vermieden.

Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

Betriebsdaten

Ein Beispiel-Verdampfer wiegt ungefähr 2 Tonnen und besteht aus Stahl. Um diese Masse wieder von 15 °C auf -35 °C abzukühlen, ist eine Kühlleistung von etwa 13,33 kWh (48 MJ) erforderlich. Daher wird durch das Ausschalten der Abtauautomatik während kurzer Produktionspausen eine Einsparung beim Verbrauch des Kompressors erzielt; pro nicht entfrostenem Verdampfer können Einsparungen von 5 bis 9 kWh<sub>e</sub> erreicht werden.

Anwendbarkeit

Angewendet beim Tiefkühlen verpackter und unverpackter Lebensmittelprodukte.

Referenzliteratur

[31, VITO, et al., 2001, 32, Van Bael J., 1998]

**4.2.12 Verpacken und Befüllen**

Im Sinne dieses Dokuments wird die Minimierung des im Zusammenhang mit dem Produktionsprozess entstehenden Verpackungsabfalls angestrebt.

In der gesamten Nahrungsmittelproduktion wird viel mit Verpackungen gearbeitet, da die Produkte für den Vertrieb und für den Verbraucher in geeigneter Weise verpackt sein müssen. Dabei muss die Verpackung Hygiene gewährleisten, Informationen vermitteln, attraktiv für den Verbraucher sein, das Produkt schützen und auf oft sehr heftig umkämpften Märkten auch die Marke zeigen und gut sichtbar sein [47, Envirowise (UK) and Aspinwall & Co., 1999]. Das gilt sowohl für Groß- als auch Einzelverpackungen. Grundsätze der Hygiene müssen berücksichtigt werden, z. B. durch die Einhaltung der HACCP-Grundsätze.

Im Vereinigten Königreich entfallen mehr als 50 % des gesamten jährlichen Verpackungsaufkommens auf den Nahrungsmittelsektor (4 bis 5 Millionen Tonnen pro Jahr). Allein das Rohmaterial für dieses Verpackungsaufkommen hat einen Wert von etwa 4.000 Millionen GBP. Im Durchschnitt stellen die Verpackungskosten im Vereinigten Königreich 13 % der Produktionskosten im Nahrungsmittelsektor dar [47, Envirowise (UK) and Aspinwall & Co., 1999].

**4.2.12.1 Auswahl des Verpackungsmaterials**Beschreibung

Die Lebenszyklusanalyse von Verpackungen sprengt den Rahmen dieses Dokuments.

Verpackungsmaterial kann so ausgewählt werden, dass die Umweltauswirkungen möglichst gering ausfallen. Um Abfälle auf ein Minimum zu begrenzen, müssen Gewicht und Volumen der einzelnen Materialien, zusammen mit ihren wiederverwerteten Inhalten, berücksichtigt werden, aber auch das Potenzial für die Wiederverwendung, Wiederverwertung und Entsorgung der Verpackungen. Oft kann ein Material den Bedarf an einem

anderen ersetzen, z. B. kann wiederverwertbare Schweißfolie den Bedarf an Pappschalen und Schweißfolie ersetzen.

Die Wahl des Verpackungsmaterials kann sich auf die Möglichkeiten für seine Wiederverwendung sowohl innerhalb der Anlage als auch außerhalb, z. B. nach dem erneuten Befüllen beim Lieferanten, auswirken.

Es ist möglich, leicht wiederverwertbare Materialien zu wählen, die Nichtverwendung von Verbundmaterialien anzustreben, Verpackungen so zu beschriften, dass die verwendeten Materialien ersichtlich sind, und die Kreuzkontamination von Materialien, z. B. Papieretiketten auf Kunststoffhüllen, einzuschränken. Dazu ist die Zusammenarbeit zwischen dem Hersteller oder Lieferanten der Verpackung und der Anlage zur Nahrungsmittelproduktion erforderlich, und in den meisten Fällen auch mit dem nachgeordneten Kunden, insbesondere dann, wenn es sich dabei um einen Einzelhändler handelt. Eine Lieferfirma nimmt unter Umständen eher Lieferungen in Großpackungen an und benötigt keine auffallenden Verpackungen.

Die Auswahl der Verpackungsmaterialien muss anhand der wesentlichen Anforderungen in Artikel 9 und Anhang II der Richtlinie 94/62/EG zu Verpackungen und Verpackungsabfall [213, EC, 1994] erfolgen. Dazu zählt die Minimierung von giftigen oder anderweitig gefährlichen Substanzen und Materialien hinsichtlich ihres Auftretens in Emissionen, Asche oder Sickerflüssigkeiten beim Verpacken oder in Rückständen, wenn sie letztlich verbrannt oder auf Mülldeponien gelagert werden. Die Wiederverwertung von Verpackungen kann zu Emissionen in die Umwelt führen, die sich sowohl aus dem Verpackungsmaterial selbst auch aus den Rückständen des Produkts, das die Verpackungen enthalten haben, ergeben können. Es gibt Grenzwerte für die zulässigen Konzentrationen von Cadmium, Quecksilber, Blei und sechswertigem Chrom. Die Eignung zur Rückgewinnung von Material durch Wiederverwertung und/oder Kompostierung, also deren biologische Abbaubarkeit und Energierückgewinnung, d. h. der Heizwert, müssen berücksichtigt werden. Weitere Einzelheiten sind in Richtlinie 94/62/EG enthalten. Das Entleeren, Sammeln, Sortieren, Trennen und Wiederverwerten, das für die spätere Wiederverwendung der rückgewonnenen Materialien erforderlich ist, hängt von den eingesetzten Materialien und Materialkombinationen ab.

So können beispielsweise natürliche, nicht chemisch modifizierte Materialien wie Holz, Holzfasern, Baumwollfasern, Zellstoff und Jute ohne weitere Prüfung als biologisch abbaubar akzeptiert werden.

### Erreichbare Umweltvorteile

Geringerer Verbrauch nichterneuerbarer Materialien und weniger Abfallaufkommen.

### Medienübergreifende Effekte

Verpackungen, die für die Wiederverwendung vorgesehen sind, sind oft schwerer als gleichwertige Einwegverpackungen, sodass für Handhabung und Transport unter Umständen mehr Energie erforderlich ist. Verpackungen, die mit dem Produkt in Berührung kommen können, müssen vor der Wiederverwendung gereinigt werden, sodass Wasser und Reinigungsmittel verbraucht werden und Abwasser anfällt.

### Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

### Wirtschaftlichkeit

Geringere Abfallentsorgungskosten.

### Anlass für die Umsetzung

Gesetzliche Vorgaben, insbesondere Richtlinie 94/62/EG.

### Referenzliteratur

[64, Environment Agency of England and Wales, 2001, 213, EC, 1994]

## **4.2.12.2 Optimierung des Verpackungsdesigns zur Mengenreduktion**

### Beschreibung

Die Lebenszyklusanalyse von Verpackungen sprengt den Rahmen dieses Dokuments.

Verschmutzung durch Verpackungsabfall wird entsprechend der Abfallminimierungshierarchie verhindert, also durch Vermeidung von Verpackungen, Reduzierung von Verpackungen, Wiederverwendung von Verpackungen und Wiederverwertung von Verpackungen.

Es kann die optimale Menge an Primär- und Sekundärverpackungen verwendet werden, wie sie sich unter Berücksichtigung von Produktgröße, -form, -gewicht sowie Vertriebsanforderungen und ausgewähltem Verpackungsmaterial ergibt. Die Verpackung kann so ausgewählt werden, dass sie ihren Zweck erfüllt und die Menge des verwendeten Verpackungsmaterials minimiert, die Menge des Produkts pro Palette maximiert und die Lagernutzung optimiert werden. Das ist auch möglich, während gleichzeitig gewährleistet wird, dass die Verpackung das erforderliche Maß an Produktschutz bietet, und ohne das Risiko von Produktverlusten zu steigern.

Die Auswahl der Verpackungen und Verpackungsmaterialien muss anhand der wesentlichen Anforderungen in Artikel 9 und Anhang II der Richtlinie 94/62/EG zu Verpackungen und Verpackungsabfall [213, EC, 1994] erfolgen. Eine Möglichkeit, diese Vorgaben einzuhalten, besteht darin, nach harmonisierten Normen zu arbeiten wie z. B. EN 13428, Verpackung – Spezifische Anforderungen an die Herstellung und Zusammensetzung – Ressourcenschonung durch Verpackungsminimierung (das Arbeiten nach dieser Norm führt zur Einhaltung des dritten Einschubs von Anhang II (1) der Richtlinie) und EN 13432, Verpackung – Anforderungen an die Verwertung von Verpackungen durch Kompostierung und biologischen Abbau – Prüfschema und Bewertungskriterien für die Einstufung von Verpackungen. Zum Zeitpunkt der Abfassung dieses Dokuments waren weitere harmonisierte Normen in Vorbereitung.

#### Erreichbare Umweltvorteile

Weniger Materialverbrauch für Verpackungen und weniger Abfall sowohl in der Anlage als auch am Ort des Auspackens.

#### Betriebsdaten

Ein Konditoreiwarenunternehmen investierte in eine neue Einwickelmaschine, die es ihm ermöglichte, die inneren Gebindefolien seiner Kekse-Umverpackungen abzuschaffen. Der Polypropylenverbrauch ging dadurch um 100 t/Jahr zurück.

Ein Tierfutterunternehmen senkte die Seitenhöhe seiner Kartontransportkisten, ohne deren Tragfähigkeit zu beeinträchtigen. Dadurch wurde der Abfall verringert und der Gebrauch von Wellpappe und Tinte ging um 49 % zurück.

In einer Marmeladen- und Erdnussbutterfabrik wurde in einer Untersuchung einer Verpackungslinie festgestellt, dass die statische Aufladung des Hüllfilms zu Ausfällen bei der automatischen Anbringung der Folien gegen unbefugte Eingriffe führte. Durch eine Erhöhung der Filmstärke um 20 µm konnte die Maschinengeschwindigkeit von 250 Gläsern pro Minute beibehalten werden, während die Ausfälle um 40 % zurückgingen. Die so erzielten Einsparungen an Filmabfällen allein betragen 25.000 GBP/Jahr.

#### Anwendbarkeit

In vielen Bereichen anwendbar.

#### Wirtschaftlichkeit

Das Konditoreiwarenunternehmen gab einen Amortisationszeitraum von weniger als 2 Jahren an. Das Tierfutterunternehmen gab jährliche Einsparungen von 100.000 GBP an.

#### Anlass für die Umsetzung

Geringerer Verbrauch von Verpackungsmaterial.

#### Beispielanlagen

Ein Kekshersteller und ein Tierfutterhersteller.

#### Referenzliteratur

[11, Environment Agency of England and Wales, 2000, 31, VITO, et al., 2001]

### **4.2.12.3 Trennung von Verpackungsmaterial zur Optimierung von Gebrauch, Wiederverwendung, Rückgewinnung, Wiederverwertung und Entsorgung**

#### Beschreibung

Lieferanten von Rohmaterial, Zusatzstoffen und Reinigungskemikalien können ihre leeren Behälter aus beispielsweise Kunststoff, Holz oder Metall für die Wiederverwertung zurücknehmen. Das kann sowohl für den

Betreiber der Anlage als auch den Lieferanten einfacher sein, wenn sie sich darauf einigen, die größtmöglichen Behälter zu verwenden. Darüber hinaus können gebrauchte Verpackungsmaterialien, sofern sie von anderen Materialien getrennt werden, zur Wiederverwertung gebracht werden, wenn sie sich nicht wiederverwenden lassen.

Durch die Trennung von Verpackungsabfällen können sich Möglichkeiten für die Wiederverwertung von Abfall und für die Verringerung der auf Deponien verbrachten Mengen ergeben. Sogar ein Verkauf ist unter Umständen möglich. Das Trennen kann ganz einfach erfolgen, z. B. indem Papier, Holz, Kunststoffe und Lebensmittel in verschiedene Behälter gegeben werden. Oder es kann in einem komplizierteren Verfahren erfolgen, z. B. durch Einsatz eines Mazerators, der beim Trennen der Verpackung vom Produkt hilft.

So können beispielsweise Kunststoffschutzfolien, die Flaschen auf dem Weg zur Abfülllinie umgeben, gesammelt, zu Ballen gepresst und zur Wiederverwertung gegeben werden.

### Erreichbare Umweltvorteile

Beugt Abfallentstehung vor und erleichtert die Wiederverwertung sowohl von Verpackungs- als auch von Nahrungsmittelmaterien.

### Medienübergreifende Effekte

Wenn leere Behälter ungereinigt zurückgegeben werden, treten keine medienübergreifenden Auswirkungen auf. Behälter, die in direkten Kontakt mit Lebensmitteln kommen, müssen die vorgeschriebenen Hygienestandards erfüllen, müssen also vor der Wiederverwendung gereinigt werden. Dadurch kann es zu Staubemissionen, Chemikalienverbrauch, Abwasserentstehung und Energieverbrauch kommen. Der Transport vom Verbraucher zurück zum Lieferanten ist mit Umweltbelastungen verbunden.

### Betriebsdaten

Ein Desserthersteller entwickelte selbst eine Maschine, mit der er Fehlprodukte am Ende des Prozesses von ihrer Verpackung trennen kann. Dadurch wurde es möglich, Kunststoff-Karton-Verpackungen zu kompaktieren und wiederzuverwerten und den festen Produktabfall mit flüssigen Lebensmittelabfällen zu vermischen und als Schweinefutter zu verkaufen. Das Ergebnis war eine geringere Abfallmenge sowie geringere Kosten für Abfallentsorgung und Abwasserbehandlung.

Flaschen, große und kleine Fässer, Kunststoff- und Metallkisten, mittlere Großpackungen, Paletten, Trommeln, Kunststoffkisten und Kunststoffschalen können wiederverwendet werden. Pappe, Papier, Kunststoff, Glas und Metalle lassen sich wiederverwerten. Diese Verpackungsmaterialien können an der Stelle der Anlage gesammelt werden, wo sie geleert werden.

Damit die Verpackungen wiederverwendet werden können, müssen die Unternehmen entsprechende Vorkehrungen treffen, z. B. die Einrichtung eines geschlossenen Kreislaufs, in dem die Verpackung zur Wiederverwendung zurückgegeben werden kann. Angaben zufolge ist das meist effektiver, wo relativ kurze Transportwege vorliegen. Der Einsatz eines Tracking-Systems, z. B. mit Strichcodes, kann bei der Verwaltung von im Transit befindlichen Verpackungen helfen.

### Anwendbarkeit

In allen neuen und bestehenden Anlagen der Nahrungsmittelproduktion anwendbar, in denen verschiedene Verpackungsmaterialien zum Einsatz kommen.

### Wirtschaftlichkeit

Die wirtschaftlichen Daten unterscheiden sich von Standort zu Standort und sind abhängig von den mit Lieferanten und/oder Wiederverwertern getroffenen Vereinbarungen. Die Abfallentsorgungs- und Abfallbehandlungskosten gehen zurück.

### Anlass für die Umsetzung

Abfallvermeidung, Wiederverwertungspläne für Abfall und gesetzliche Bestimmungen für Verpackungsabfall. Weniger Abfallaufkommen und damit verbundene Entsorgungskosten.

### Beispielanlagen

Mindestens ein Desserthersteller im Vereinigten Königreich.

### Referenzliteratur

[11, Environment Agency of England and Wales, 2000, 31, VITO, et al., 2001]

#### 4.2.12.4 Optimierung der Effizienz von Verpackungslinien

##### Beschreibung

Schlecht geplante und betriebene Verpackungslinien führen bei vielen Unternehmen zu einem Verlust von bis zu 4 % von Produkt und Verpackung. Zur Verbesserung von Effizienz und Produktivität und zur Verringerung von Abfällen können einzelne Maschinen sachgerecht so geplant werden, dass sie zusammen nach einem effizienten Gesamtplan arbeiten.

Es ist wichtig, die langsamste Maschine der Produktionslinie mit maximaler Kapazität laufen zu lassen. Idealerweise wird ihre Zufuhr niemals unterbrochen. Die Effizienz von Verpackungslinien kann überwacht werden, z. B. auf Wochenbasis, indem Schlüsselindikatoren für die Leistung gemessen werden, wie beispielsweise das Verhältnis von Abfall zu Produktion. Die optimalen und tatsächlichen Planungswerte der Verpackungsmaschine können graphisch aufgetragen werden, damit sichtbar wird, ob die Maschine mit optimaler Effizienz arbeitet. Auch mit der graphischen Darstellung anderer Werte lässt sich die Zuverlässigkeit einzelner Maschinen aufzeigen. Schlüsselindikatoren für die Leistung sind unter anderem die Zahl der während einer Schicht oder eines Tages aufgetretenen zu verwerfenden Produkte sowie die Ausfallzeiten.

##### Erreichbare Umweltvorteile

Geringere Nahrungsmittel- und Verpackungsverluste.

##### Medienübergreifende Effekte

Normalerweise keine. In einem der im nachfolgenden Betriebsdatenabschnitt genannten Beispiele wurde jedoch eine dickere Folie verwendet, was aber durch die Abfalleinsparungen ausgeglichen wurde.

##### Betriebsdaten

In einer großen Beispielbrauerei wurden zur Vermeidung einer schlechten Effizienz der Verpackungslinien Teams eingerichtet, die die Leistung überwachen und Problembereiche erkennen sollten. Die genaue Analyse der Verpackungslinien erlaubte es, Maßnahmen zu ergreifen, mit denen die Ausfallzeiten reduziert und die Effizienz vergrößert werden konnte. Das Ergebnis waren geringere Betriebskosten und weniger Abfall, wodurch Kosteneinsparungen von mehr als 137.000 GBP/Jahr erzielt wurden.

Eine Studie in einer Molkerei ergab, dass sich die Sensoren einer Verpackungslinie an der Schüttrinne für Flaschenverschlüsse zu dicht an der Befüllungsvorrichtung befanden. Dadurch wurden die Sensoren mit Milchschaum bedeckt und konnten Blockaden bei den Flaschenverschlüssen nicht mehr erkennen. Das führte zum Verwerfen von bis zu 20.000 Flaschen pro Woche. Durch Umsetzen der Sensoren konnte das Unternehmen 35.000 GBP/Jahr an Entsorgungskosten für unbrauchbare Poly-Flaschen und weitere 5.000 GBP/Jahr an Milchabfall- und Wiederaufbereitungskosten einsparen. Dazu kam noch der Nutzen aus der gesteigerten Produktion.

##### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion, d. h. in neuen und bestehenden Anlagen, in denen automatische Abfüllanlagen vorhanden sind.

##### Wirtschaftlichkeit

Siehe oben, Angaben zu Einsparungen in den Beispielanlagen, unter Betriebsdaten.

##### Anlass für die Umsetzung

Weniger Produkt- und Verpackungsverwundung und entsprechende Kosteneinsparungen.

##### Beispielanlagen

In der Nahrungsmittelproduktion und anderen Branchen weit verbreitet.

##### Referenzliteratur

[11, Environment Agency of England and Wales, 2000]

### 4.2.12.5 Abfallminimierung durch Optimierung der Geschwindigkeit von Verpackungslinien

#### Beschreibung

Die Leistung von Verpackungslinien lässt sich optimieren und eine passende Maschinengeschwindigkeit kann eingestellt werden, um sicherzustellen, dass das Produkt in genauen Mengen abgewogen wird, die auf den Betrieb des Heißsiegelgeräts abgestimmt sind.

#### Erreichbare Umweltvorteile

Weniger Produkt- und Verpackungsverluste.

#### Betriebsdaten

In einem Beispielunternehmen, das Süßwaren herstellt, wurde die Leistung seiner Verpackungslinien überwacht und festgestellt, dass eine ungeeignete Maschinengeschwindigkeit zu einer fehlerhaften Produkteinwaage und zum Versagen des Heißsiegelgeräts führte. Durch einfache Anpassung der Maschinengeschwindigkeit ergaben sich Einsparungen bei Produkt, Verpackung, erneuter Verarbeitung und Abfallentsorgung. Weitere Vorteile waren eine gesteigerte Produktion und eine Abfallverringerung um 500 t/Jahr.

#### Anwendbarkeit

Anwendbar in allen Unternehmen der Nahrungsmittelproduktion, die Form-Füll-Verschließmaschinen einsetzen.

#### Wirtschaftlichkeit

Im Beispielunternehmen wurden Einsparungen von mehr als 120.000 GBP/Jahr erzielt. Andere finanzielle Vorteile gingen mit der Produktionssteigerung und dem Rückgang des auf Deponien entsorgten Abfalls einher.

#### Anlässe für die Umsetzung

Bessere Produktionseffizienz.

#### Beispielanlagen

Mindestens ein Süßwarenhersteller im Vereinigten Königreich.

#### Referenzliteratur

[11, Environment Agency of England and Wales, 2000]

### 4.2.12.6 Einsatz von Kontrollwaagen in der Prozesslinie zur Vermeidung von Verpackungsüberfüllungen

#### Beschreibung

Durch die Verwendung von Kontrollwaagen in der Prozesslinie kann der Produktverlust durch Überfüllungen reduziert werden. Produktverluste durch Überfüllung können durch Überlaufen sowie durch zu verpackendes Material, das in der Versiegelung steckenbleibt und diese kontaminiert, z. B. bei Form-Füll-Verschließmaschinen, entstehen. Dadurch kann es zu Verschüttungen und zu nicht annehmbaren Produkten kommen. Techniken wie die statistische Prozesskontrolle können angewandt werden, um Überfüllungen zu überwachen und um festzustellen, wann die Geräte neu eingestellt werden müssen. Auch ein wachsamer, geschulter Bediener, der dafür sorgt, dass die Befüllungsmaschine stets optimal eingestellt ist, kann dies erreichen.

#### Erreichbare Umweltvorteile

Weniger vermeidbarer Abfall, wenn Überfüllungen zu Verschüttungen oder Verunreinigung von Verpackungsversiegelungen führt.

#### Betriebsdaten

Bei einer neuen Maschine, die mit einer Füllmenge von 400 g betrieben wird, lässt sich die Standardabweichung auf 0,5 g, also 0,125 %, begrenzen. Bei älteren Maschinen kann dieser Wert sogar höher liegen, z. B. zwischen 0,15 % und 0,25 %.

#### Anwendbarkeit

Anwendbar in allen Anlagen mit automatischen Abfüllanlagen.

Wirtschaftlichkeit

Finanzielle Einsparungen, weil nicht mehr als nötig in die Packungen gefüllt wird, und dadurch, dass weniger Verluste durch Verschüttungsabfälle entstehen.

Anlass für die Umsetzung

Einhaltung von gesetzlichen Vorgaben zu „Maßen und Gewichten“.

Beispielanlagen

In Anlagen der Nahrungsmittelproduktion können mit neuen Abfüllmaschinen Überfüllungen auf 0,125 % begrenzt werden; bei älteren Maschinen liegen diese Werte zwischen 0,15 % und 0,25 %.

Referenzliteratur

[11, Environment Agency of England and Wales, 2000, 198, FPME, 2003]

**4.2.13 Erzeugung und Verbrauch von Energie****4.2.13.1 Kraft-Wärme-Kopplung (KWK) – Überblick über die Situation in Europa**

Im Jahr 1998 stellte die Stromproduktion mittels KWK 11 % der EU-15-Gesamtstromproduktion dar; das bedeutete Energieeinsparungen in der Größenordnung des jährlichen Bruttoenergieverbrauchs von Österreich oder Griechenland. Ein Entwurf für eine Richtlinie, die zum Energiesparen und zur Vermeidung des Klimawandels durch die Förderung der KWK beitragen soll, wurde von der EG am 23. Juli 2002 vorgelegt [90, EC, 2002]. Die vorgeschlagene Richtlinie soll die Mitgliedsstaaten dazu ermuntern, die KWK durch systematische Untersuchung und progressive Umsetzung des jeweiligen nationalen Potenzials für hocheffiziente KWK zu fördern. Die Mitgliedsstaaten müssten dann über den Fortschritt hinsichtlich der Ausschöpfung dieses Potenzials und die dazu ergriffenen Maßnahmen berichten.

**4.2.13.1.1 Kraft-Wärme-Kopplung (KWK)**Beschreibung

Die Kraft-Wärme-Kopplung (KWK) ist eine Technik zur Erzeugung von Wärme und Strom in einem einzigen Prozess. Die innerbetriebliche KWK kann in der Nahrungsmittelproduktion zum Einsatz kommen, wenn Wärme und Strom gleichermaßen gebraucht werden. So erfordert beispielsweise die Zuckerherstellung elektrische und thermische Energie in jedem Schritt des Prozesses. Strom wird für die Beleuchtung, die Steuerung der Anlagenprozesse und als Antriebskraft für Maschinen benötigt. Dampf und heißes Wasser werden für die Beheizung von Prozessgefäßen und Gebäuden gebraucht. Je größer eine Molkerei, desto größer der Bedarf an thermischer und elektrischer Energie für Verdampfungs-/Trocknungsschritte, sodass die KWK zur geeigneten Alternative wird.

Erreichbare Umweltvorteile

Weniger Energieverbrauch und Luftemissionen, z. B. NO<sub>x</sub>, CO<sub>2</sub> und SO<sub>2</sub>.

Betriebsdaten

Die Energieeffizienz der KWK kann bis zu 90 % betragen. Dadurch werden die Nutzung fossiler Brennstoffe optimiert und die CO<sub>2</sub>-Produktion verringert. Neue KWK-Anlagen sparen mindestens 10 % des Brennstoffs, der andernfalls für die getrennte Erzeugung von Wärme und Strom erforderlich ist. Außerdem können mit gasbefeuerten KWK-Systemen die SO<sub>2</sub>-Emissionen eliminiert und die NO<sub>x</sub>-Werte auf gesetzlich zugelassene Grenzen beschränkt werden. Moderne KWK-Geräte lassen sich wahrscheinlich mit weniger Aufwand betreiben und warten als viele ältere Kesselsysteme, da sie mit automatischen Regel- und Überwachungsvorrichtungen ausgestattet sind.

Angaben zufolge wird der größte Teil der in der Zuckerherstellung benötigten Energie durch die Verbrennung von Gas, Heizöl oder Kohle in einem Kesselhaus erzeugt, wo sie mittels KWK-Anlagen in Dampf und Strom umgewandelt wird. In diesem Sektor liegt der Gesamtfaktor der Brennstoffnutzung bei der KWK über 70 %, meist sogar über 80 %. Diese Brennstoffumwandlungseffizienz übertrifft die sämtlicher kommerzieller Kraftwerke, deren Dampf nicht weiter genutzt wird. Das gilt selbst für die neueste Generation der kombinierten Gasturbinen, deren Effizienz bei etwa 55 % liegt. Nicht benötigter Strom kann an andere Nutzer verkauft werden.

Im Molkereisektor gilt die KWK als günstige Alternative, da für die Verdampfungs-/Trocknungsschritte sowohl Strom als auch thermische Wärme in großen Mengen benötigt wird. So ist die KWK beispielsweise bei der Trocknung von Molke und Milch weit verbreitet, wo hohe Dampftemperaturen und -drücke erforderlich sind, z. B. 220 - 240 °C und 32 – 34 bar. Auch Verluste im Leitungssystem müssen berücksichtigt werden, sodass der erzeugte Dampf einen Druck von mindestens 40 bar haben muss. Dabei wird die KWK auf Grundlage einer Gegendruckdampfturbine verwendet. Bei dieser Art von KWK-Anlage erzeugt der Dampfdruckunterschied in der Gegendruckdampfturbine die mechanische Energie für den Antrieb eines Stromgenerators. Vor der Molke- und Milchtrocknung werden geringere Dampftemperaturen und -drücke benötigt. Dieser Niederdruckdampf kann entweder durch eine Dampfdruckreduzierung mittels Drosselventilen oder durch eine KWK auf Grundlage einer Gegendruckdampfturbine erzeugt werden. Die KWK-Variante ist energieeffizienter, da bei der Dampfdruckreduktion mittels Drosselventilen Energie „vernichtet“ wird.

Wenn in der Molkerei keine Trocknung stattfindet und die erforderlichen Dampftemperaturen und -drücke erheblich geringer sind, ist die Gegendruckdampfturbine nicht sinnvoll, da die Dampfdrucksäule zu klein ist, was zu einer geringen Effizienz führt. In solchen Fällen sollen Blockheizkraftwerke mit Gas- oder Dieselmotoren oder KWK-Anlagen mit Gasturbinen und nachgeschalteten Abwärmekesseln besser geeignet sein. Abbildung 4.18 zeigt Sankey-Diagramme, in denen die Energieeffizienz einer konventionell betriebenen Gasturbine mit Generator und einer KWK-Anlage in einer Molkerei verglichen wird.

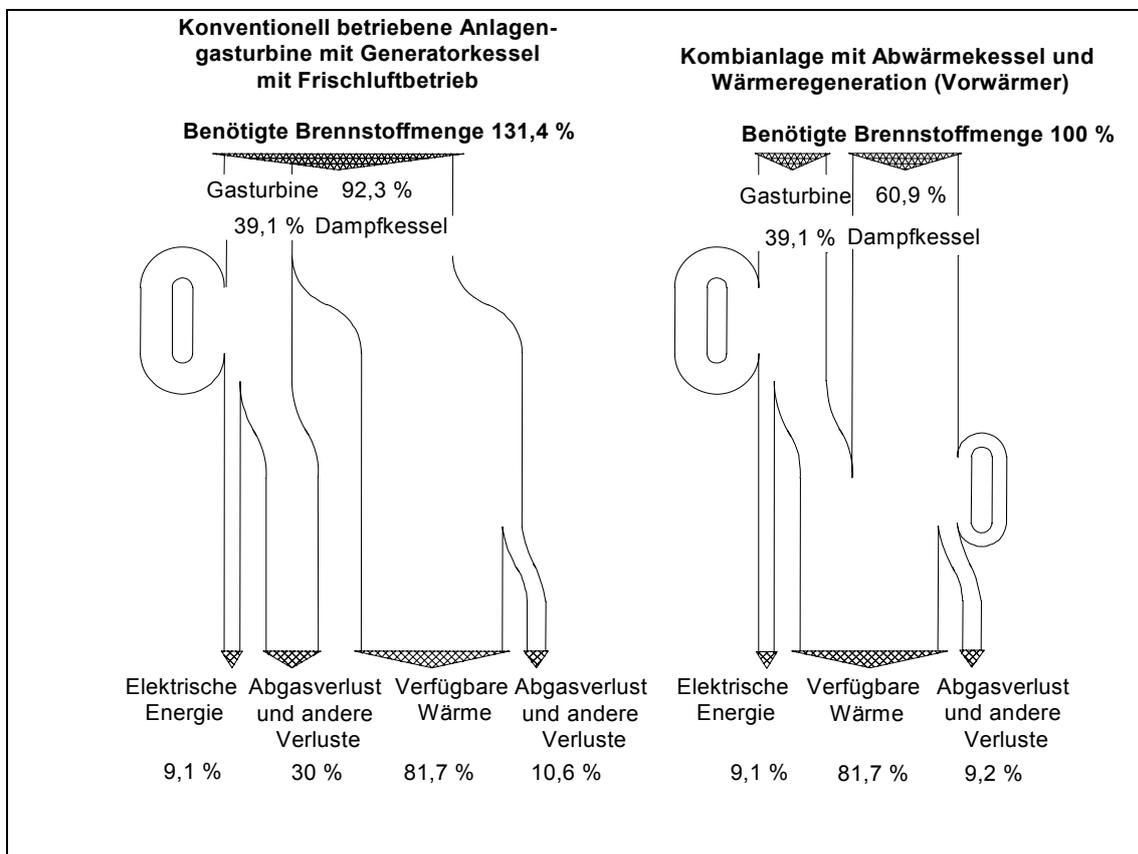


Abbildung 4.18: Vergleich der Energieeffizienz eines konventionellen Gasturbinengenerators und einer KWK-Anlage

In einer Beispielbrauerei erzeugt eine KWK-Anlage Strom mit einem 4.000-kW<sub>e</sub>-Gasturbinengenerator. Aus dem Turbinenabgas wird mit einem Abgaskessel, der eine Leistung von 11 t/Std. hat, Hochdruckdampf mit einem Druck von 1,5 MPa erzeugt. Dieser Dampf verbindet sich mit dem Hochdruckdampf der bestehenden Kessel und trägt zum Betrieb einer von einer Gegendruckdampfturbine angetriebenen Kühlmaschine mit einer Kapazität von 734 kW<sub>th</sub> bei. Abdampf von der Gegendruckturbine mit einem auf 0,6 MPa abgesenkten Druck wird als Wärmequelle für den Betrieb einer Ammoniakabsorptionskühlmaschine mit einer Kapazität von 1,93 kW<sub>th</sub> benutzt, die ein Sekundärkältemittel, z. B. Lake, zur Kühlung von Bier liefert. Das System nutzt also kaskadisch die Dampfenergie und senkt den Strombedarf der Brauerei insgesamt um 820 kW, wobei 220 kW auf den dampfturbinengetriebenen Motor und 600 kW auf das Ammoniakabsorptionskühlgerät entfallen. Wenn der Prozess chargenweise durchgeführt wird, bleibt der Dampfbedarf nicht konstant. Wenn in einem solchen

Fall nur ein dampfturbinengetriebenes Kühlgerät zur Erzeugung von Kühlenergie eingesetzt würde, so wäre seine Verfügbarkeit größtenteils von diesem instabilen Dampfbedarf abhängig. Angaben zufolge kann dieses System in Anlagen zur Herstellung von Speiseeis eingesetzt werden, da diese ebenfalls viel Strom und Kühlenergie verbrauchen. Abbildung 4.19 zeigt ein Flussdiagramm dieses KWK-Systems in einer Brauerei.

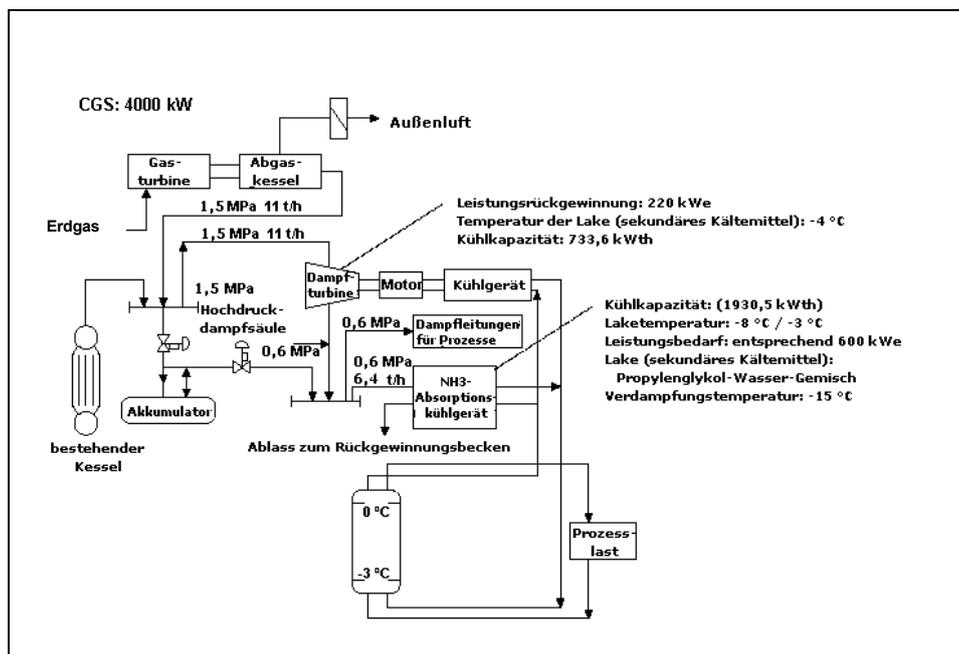


Abbildung 4.19: Flussdiagramm eines KWK-Systems in einer Brauerei<sup>12</sup>

Mit dem oben beschriebenen KWK-System sank der Energieverbrauch der Brauerei (Strom und Brennstoff) um 14 % und der Strombedarf um 40 %. Die Gasturbine hatte eine Nennleistung von 4.200 kW bei 0 °C und wurde mit Erdgas mit niedrigem CO<sub>2</sub>-Ausstoß in einem vorgemischten Magerverbrennungssystem mit geringem NO<sub>x</sub>-Ausstoß betrieben. Die vorgemischte Magerverbrennung verbessert die Turbineneffizienz um 2 – 4 % und senkt die NO<sub>x</sub>-Emissionen auf weniger als 50 ppm, d. h. auf die Hälfte des Wertes herkömmlicher Systeme, bei denen die Verringerung der NO<sub>x</sub>-Emissionen durch Wasser- oder Dampfinjektion erreicht wird. Mit dem System gingen die NO<sub>x</sub>-Emissionen der Brauerei im Vergleich zu einem herkömmlichen System um 14,8 % und die CO<sub>2</sub>-Emissionen um 7,9 % zurück.

Es wird außerdem berichtet, dass Gasmotoren, die saubere Brennstoffe verwenden und mit hoher thermischer Effizienz arbeiten, für kleinere KWK-Anlagen, also für 1.000 kW und weniger, geeignet sind. In einer Beispielbrauerei wurde eine 596-kW-Gasmaschine mit einem Kühlsystem, das kochendes Wasser für die Dampfdruckgewinnung benutzt, installiert. Die KWK-Anlage wurde auf einem vibrationsgeschützten Fundament zusammen mit einem 560-kW-Generator, der mit einer Dampf-und-Wasser-Trommel kombiniert ist, montiert. Die Anlage gewinnt Niederdruckdampf (1 kg/cm<sup>2</sup>) direkt aus dem Kühlwasser der Maschine zurück. Das Abgas der Maschine wird zur Erzeugung von Mitteldruckdampf (8 kg/cm<sup>2</sup>) durch einen Abwärmekessel und zum Vorwärmen von Speisewasser für den Kessel durch einen Vorwärmer verwendet. Die KWK-Anlage ist mit einem Dreiwegekatalysator zum NO<sub>x</sub>-Entzug, einem Geräuschdämpfer und anderen erforderlichen Regelsystemen ausgestattet und kann von einem zentralen Stellerraum aus überwacht werden. Als Umweltnutzen werden unter anderem die Leistungserzeugung von 541 kW, geringe NO<sub>x</sub>-Emissionen und niedrige Geräuschpegel genannt. Bei 18.000 Betriebsstunden hat die KWK-Anlage eine Effizienz von 31,3 % in der Leistungserzeugung, 45,6 % in der Wärmerückgewinnung und 76,9 % insgesamt. Der von der KWK erzeugte Strom ergänzte den extern bezogenen Strom um 25 %, und der Dampf deckte 6 - 10 % des Betriebsbedarfs der Brauerei. Die Amortisationszeit liegt bei unter 4 Jahren.

#### Anwendbarkeit

In vielen Bereichen anwendbar. Die Anwendbarkeit der KWK hängt stark von mehreren technischen Aspekten ab. Auch wenn die KWK eine gut etablierte und technisch ausgereifte Technik darstellt, ist es wichtig, die richtigen Konzeptionsentscheidungen zu treffen. Die wichtigsten zu berücksichtigenden Faktoren sind die

<sup>12</sup> Anm. d. Übers. u. d. UBA-Bearb.: "Erdgas" heißt in asiatischen Ländern auch "13A Gas".

Verbrauchsmuster für Strom und Wärme in der Anlage und das Verhältnis zwischen Strom- und Wärmeverbrauch. Weiterhin wichtig ist, ob der Anlagenbetrieb durchgehend erfolgt, und ob es zu großen Veränderungen bei den Prozessen kommt. Als einfache Faustregel gilt, dass eine Anlage mindestens 4.000 Stunden/Jahr gleichzeitig Bedarf an Wärme und Strom haben muss.

### Wirtschaftlichkeit

Bei der Entscheidung für oder gegen die Nutzung einer KWK anhand einer wirtschaftlichen Betrachtung müssen die Preise für Gas und Strom berücksichtigt werden. Wenn Gas und andere Brennstoffe relativ teuer sind, Strom dagegen eher billig, so spricht das gegen die Entscheidung für die KWK. Wenn beispielsweise die Strompreise sinken oder die Gaspreise steigen, sinkt die finanzielle Rendite der KWK. In freien Energiemärkten sind diese Situationen denkbar. Die Planung einer KWK-Anlage nach dem benötigten Wärmeverbrauch ist denkbar, wenn der überschüssige erzeugte Strom an öffentliche Stromversorger verkauft werden kann. Ob es sich dabei um eine attraktive Lösung handelt, hängt stark von dem Preis ab, der für den verkauften Strom erzielt werden kann.

Hinsichtlich der Finanzierung von KWK-Anlagen besteht bei den Unternehmen der Trend zur Fremdfinanzierung. Manchmal werden Gemeinschaftsunternehmungen mit Energielieferanten gebildet, und in anderen Fällen finanzieren Dritte die KWK-Anlage vollständig. Verträge über die Bereitstellung von Strom und Wärme durch die KWK-Anlage haben normalerweise Laufzeiten von 10 bis 15 Jahren.

Im Vereinigten Königreich hat sich gezeigt, dass eine KWK inzwischen die Gesamtenergierechnung einer Anlage um 20 % senken kann. In der Beispielbrauerei betrug die Einsparung bei den Energiekosten 16,2 %.

### Beispielanlagen

Wird in Anlagen zur Zuckerherstellung, Molkereien, Brauereien und Brennereien angewendet.

### Referenzliteratur

[9, Verband der Deutschen Milchwirtschaft (German Dairy Association), 1999, 39, Verband der Deutschen Milchwirtschaft (German Dairy Association), 2001, 61, CEFS, 2001, 69, Environment Agency of England and Wales, 2001, 90, EC, 2002, 92, CADDET Energy Efficiency, 2000]

#### **4.2.13.2 Effizienz von Wärmeerzeugern**

Die Effizienz ist als das bei einem Prozess bestehende Verhältnis zwischen Energieabgabe und Energieaufnahme definiert. Die Effizienz eines Wärmeerzeugers lässt sich beschreiben als das Verhältnis zwischen der von der wärmetragenden Flüssigkeit aufgenommenen Energie und der Energiezufuhr durch den Brennstoff. Das typische Verfahren zur Berechnung der Effizienz eines Wärmegenerators ist die sogenannte „indirekte Methode“. Diese Methode beruht auf der herkömmlichen Bewertung von Verlusten durch wahrnehmbare Wärme in Rauch, unvollständiger Verbrennung und Abgabe von den Wänden des Wärmeerzeugers.

Zur Bestimmung der Verluste an den Schornstein und der Verluste durch unvollständige Verbrennung wird normalerweise so vorgegangen, dass man zwei der folgenden Parameter O<sub>2</sub>, CO<sub>2</sub> und CO misst und anhand dieser Werte mittels eines Ostwald-Diagramms die prozentualen Verluste bestimmt.

Streuverluste durch die Wände des Wärmeerzeugers bleiben im Allgemeinen bezogen auf die Laständerungen konstant und können anhand von Diagrammen bewertet werden, die der Kesselhersteller mitliefert.

Zur Überwachung der Effizienz werden folgende Kontrollen durchgeführt:

- Analysen von Rauch und O<sub>2</sub>
- Verbrauch von Brennstoff und Luft bei der Verbrennung
- Druck, Temperatur und Kapazität des wärmetragenden Mediums im Wärmeerzeuger, z. B. des diathermischen Öls, sowie der wärmetragenden Flüssigkeiten zum Verbraucher, z. B. von Dampf oder überhitztem Wasser.

#### 4.2.13.2.1 Verbesserung der Effizienz von Wärmeerzeugern

##### Beschreibung

Mit der indirekten Methode zur Bestimmung der Effizienz eines Wärmeerzeugers wurden die optimalen Werte für die Dampfanalyse eines mit Methan befeuerten Wärmeerzeugers mit diathermischem Öl in einer Anlage, die mehr als 300 t Teigwaren pro Tag produziert, herausgefunden. Die Werte sind in Tabelle 4.21 angegeben.

|  |                         |
|--|-------------------------|
| O <sub>2</sub> (Volumenprozent in trockenem Rauch) | 3 %                     |
| CO   | <70 mg/Nm <sup>3</sup>  |
| Gasförmiges NO <sub>x</sub>                        | <250 mg/Nm <sup>3</sup> |

**Tabelle 4.21: Optimalwerte der Rauchanalyse in einer Anlage zur Herstellung von Teigwaren**

Die Effizienz eines Wärmeerzeugers lässt sich verbessern, indem Verluste gemindert oder die Effizienz der Wärmeübertragung durch das wärmetragende Medium erhöht wird. Um Verluste im Rauch zu verringern, kann die Temperatur des an den Schornstein abgegebenen Rauchs gesenkt werden, sodass Verluste in Form von wahrnehmbarer Wärme gemindert werden. Auch kann die überschüssige Luft so reguliert werden, dass sie genau dem durch den eintreffenden Brennstoff erzeugten Bedarf gerecht wird und so Verluste durch unvollständige Verbrennung reduziert werden.

##### Erreichbare Umweltvorteile

Geringerer Energieverbrauch und geringere Luftemissionen.

##### Betriebsdaten

In einer Beispielanlage, in der Teigwaren hergestellt werden, wurde die Temperatur des an den Schornstein abgegebenen Rauchs gesenkt, um Wärmeverluste durch den Schornstein zu verringern, die etwa 50 % des Gesamtverlusts ausmachten. Die überschüssige Luft wurde so eingestellt, dass eine unvollständige Verbrennung vermieden wurde.

In bestehenden Anlagen kann die Effizienz um 85 % bis 90 % ansteigen, bei einer Reduktion der CO<sub>2</sub>-Emissionen um 5,5 % bis 6,5 %. In neuen Anlagen kann die Effizienz über 91 % liegen, bei einer Reduktion der CO<sub>2</sub>-Emissionen um mehr als 7,6 %.

Außerdem wurde durch Vorwärmen der Verbrennungsluft durch Rauchrückgewinnung pro 50 °C Absenkung der Rauchtemperatur eine Steigerung der Effizienz um 2 % bewirkt. Die Temperatur der vorgewärmten Luft schwankt allgemein zwischen 170 und 200 °C.

Bei bestehenden Wärmeerzeugern mit sachgerechter Verbrennung kann eine Effizienz von 90 % erreicht werden. Bei neuen Wärmeerzeugern, die mit diathermischem Öl und mit einer Rauchrückgewinnung zum Vorwärmen der Verbrennungsluft arbeiten, kann bei wirtschaftlicher Belastung eine Effizienz von 92 % und bei maximaler Belastung eine Effizienz von 91 % erzielt werden.

##### Anwendbarkeit

In neuen und bereits bestehenden Anlagen der Nahrungsmittelproduktion anwendbar.

##### Wirtschaftlichkeit

Die Kosten der Umsetzung sind bei bestehenden Anlagen gering, bei neuen Anlagen jedoch hoch.

##### Beispielanlagen

Ein Teigwarenhersteller in Italien.

##### Referenzliteratur

[150, Unione Industriali Pastai Italiani, 2002]

#### 4.2.13.3 Isolierung von Leitungen, Gefäßen und Ausrüstungen

##### Beschreibung

Durch die Isolierung von Leitungen, Gefäßen und Geräten wie Öfen und Tiefkühlgeräten lässt sich der Energieverbrauch minimieren. Die Isolierung kann durch die Wahl effektiver Beschichtungsmaterialien mit

geringer Leitfähigkeit und hoher Dicke sowie durch die Verwendung von Leitungen, Gefäßen und Geräten optimiert werden, die bereits vor der Installation isoliert sind<sup>13</sup>. Die Vorisolierung hat den Vorteil, dass z. B. Leitungshalterungen außerhalb der Isolierschicht befestigt werden und nicht direkt mit den Leitungen verbunden sind. Dadurch werden Wärmeverluste über die Halterungen verringert.

Unzureichende Isolierung von Rohrleitungen kann zu einer übermäßigen Erwärmung der umgebenden Verarbeitungsbereiche sowie zu einem Brandverletzungsrisiko führen.

### Erreichbare Umweltvorteile

Geringerer Energieverbrauch und damit geringerer Brennstoffverbrauch und weniger Luftemissionen.

### Betriebsdaten

Durch die Isolierung von Leitungen, Becken und Tanks kann der Wärme-/Kälteverlust um 82 - 86 % verringert werden. Darüber hinaus lassen sich durch Verwendung von vorisolierten Leitungen anstelle herkömmlich isolierter Leitungsrohre weitere 25 - 30 % Wärme einsparen.

In Molkereien werden warme und kalte Produkte gelagert und gepumpt. In einer neuen Beispielmolkerei in Dänemark wurden alle Rohrleitungen, die einen Temperaturunterschied von mindestens 10 °C oberhalb der Umgebungstemperatur aufwiesen, mit einer 30 mm dicken Isolierschicht versehen. Tanks wurden mit einer 50 mm dicken Isolierschicht verkleidet. Es wurden vorisolierte Röhren mit einer Umhüllung aus mit Mineralwolle gefülltem Blech verwendet. Mehr als 9 km Rohrleitungen und 53 Tanks wurden isoliert. Die errechneten Energieeinsparungen betragen 6.361 MWh/Jahr an Heizenergie und 2.397 MWh/Jahr an Kühlenergie, was einer Stromersparnis von 479 MWh/Jahr entspricht.

In einer italienischen Beispielanlage für die Teigwarenherstellung wurden die Rohrleitungen auf der gesamten Länge auf Energieverluste untersucht und die Isolierung verbessert. An drei Stellen wurde der Widerstand erhöht, und zwar von jeweils 0,22 auf 0,396 m<sup>2</sup>·°C/W, 0,574 und 0,753 m<sup>2</sup>·°C/W. Dadurch wurden Verringerungen der CO<sub>2</sub>-Emissionen um 44,4 %, 61,6 % und 70,7 % erzielt.

### Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion (neuen und bestehenden) anwendbar. Vorisolierte Leitungen sind in neuen Anlagen und dort anwendbar, wo Rohrleitungen, Gefäße und Geräte ausgetauscht werden.

### Wirtschaftliche Aspekte

In einer neuen dänischen Beispielmolkerei betragen die Investitionskosten bei einem Amortisationszeitraum von 7,6 Jahren etwa 1.408.000 EUR.

### Anlass für die Umsetzung

Senkung der Energiekosten.

### Beispielanlagen

In der Nahrungsmittelproduktion und anderen Branchen weit verbreitet.

### Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001, 150, Unione Industriali Pastai Italiani, 2002]

## **4.2.13.4 Wärmepumpen für die Wärmerückgewinnung**

### Beschreibung

Das Funktionsprinzip einer Wärmepumpe beruht auf der Wärmeübertragung von einer niedrigeren auf eine höhere Temperatur mithilfe elektrischen Stroms. Ein Beispiel ist die Wärmerückgewinnung aus warmem Kühlwasser. Das Kühlwasser wird gekühlt, und die Wärme kann zum Erwärmen von Heißwasser verwendet werden.

### Erreichbare Umweltvorteile

Geringerer Energieverbrauch durch Wärmerückgewinnung.

### Medienübergreifende Effekte

Wärmepumpen benötigen Strom.

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<sup>13</sup> Anm. d. UBA-Bearb.: d.h. Vorisolierung beim Hersteller von Rohrleitungen etc vor Einbau an der Anlage.

Betriebsdaten

Den Angaben zufolge soll es 1997 mehr als 16 Nahrungsmittelunternehmen in Australien gegeben haben, die über 30 Wärmepumpentrockner für die Niedertemperaturtrocknung von Nahrungsmitteln einsetzen. Der Wärmepumpentrockner besteht aus einer herkömmlichen Trockenkammer mit einem Luftzirkulationssystem und den üblichen Bestandteilen eines Klimakühlsystems. Die Trocknungsluft wird durch einen Verdampfer entfeuchtet, der den Kühlbereich des Kühlzyklus darstellt, und vom Verdichter der Wärmepumpe wieder erwärmt. Die Energieeffizienz, die als spezifische Feuchtigkeitsextraktionsrate ausgedrückt wird, also als kg entzogenes Wasser/kWh verbrauchter Energie, liegt zwischen 1 und 4, mit einem Durchschnittswert von 2,5 kg/kWh. Wirbelschichttrockner sind für klebrige oder unregelmäßig geformte Materialien nicht geeignet. Die zwei Trockner können in Reihe geschaltet sein. Entfeuchtete Luft von der Wärmepumpe wird zuerst in das Wirbelschichtbett mit dem halbtrockneten Produkt geleitet. Anschließend passiert der Luftstrom die Trockenkammer. Angaben zufolge lässt sich mit einer solchen Kombination die Energieeffizienz um bis zu 80 % steigern.

Anwendbarkeit

Es wird eine gute Wärmequelle benötigt. Gleichzeitig muss in der Nähe der Quelle ein Bedarf an Wärme bestehen.

Wirtschaftliche Aspekte

Die wirtschaftliche Machbarkeit ist abhängig vom Preisverhältnis zwischen Brennstoff und Strom.

Anlass für die Umsetzung

Geringere Kosten für Energie und Wasser.

Beispielanlagen

Mehrere Nahrungsmittelunternehmen in Australien.

Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001, 73, CADDET UK National team, 1997]

**4.2.13.5 Wärmerückgewinnung aus Kühlsystemen**Beschreibung

Wärme kann aus Kühlgeräten und Kompressoren rückgewonnen werden. Dazu werden Wärmetauscher und Speichertanks für warmes Wasser benötigt. Je nach Kühlgerät können Temperaturen von 50 - 60 °C erzielt werden.

Erreichbare Umweltvorteile

Geringerer Energieverbrauch durch Wärmerückgewinnung.

Betriebsdaten

Angaben zufolge kann die rückgewonnene Wärme zur Erwärmung von Leitungswasser oder Belüftungsluft, zum Auftauen gefrorener Waren oder zum Vorwärmen von Reinigungsflüssigkeiten oder des Produkts benutzt werden.

Die Installation eines Wärmerückgewinnungssystems in der Kühleinheit einer nordeuropäischen Molkerei, die sowohl Schrauben- als auch Kolbenverdichter umfasst und über eine Kühlkapazität von 3.200 kW verfügt, führte zu Energieeinsparungen von etwa 1.200.000 kWh/Jahr.

Anwendbarkeit

In neuen Anlagen in vielen Bereichen einsetzbar. In bestehenden Anlagen kann Platzmangel die Anwendung einschränken. Die Technik ist in Anlagen mit Tiefkühlagern wirtschaftlich tragbar, da normale Kühlagerbereiche im Winter keine ausreichenden Wärmemengen erzeugen.

Wirtschaftliche Aspekte

Geringere Energiekosten. In der oben angeführten nordeuropäischen Beispielmolkerei betragen die Investitionskosten etwa 160.000 EUR bei einem Amortisationszeitraum von 6,3 Jahren.

Beispielanlagen

Eine Molkerei in einem nordeuropäischen Land.

### Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001]

#### **4.2.13.6 Abschalten nicht benötigter Ausrüstungen**

##### Beschreibung

Es gibt viele einfache Energiesparmaßnahmen, die nichts oder wenig kosten, und die von einzelnen Mitarbeitern umgesetzt werden können, z. B. das Abschalten von Geräten wie Verdichtern oder das Ausschalten von Beleuchtung. Pumpen und Gebläse, die kalte Luft, gekühltes Wasser oder Frostschutzmittel umwälzen, erzeugen Wärme und erhöhen damit die Kühllast um den größten Teil der von ihnen verbrauchten Energie; deshalb wird Energie gespart, wenn diese Geräte abgeschaltet werden, solange sie nicht gebraucht werden. Dasselbe gilt für die Beleuchtung in Kaltlagerbereichen und Kühlräumen, die ebenfalls die Kühllast um den größten Teil der von ihr verbrauchten Energie erhöht.

Das Abschalten kann nach einem festgelegten Programm oder Zeitplan erfolgen. Umgebungsbedingungen können überwacht werden, sodass beispielsweise zu hohe oder zu niedrige Temperaturen erkannt werden, und Motoren können bei Nichtbedarf abgeschaltet werden. Die Belastung von Motoren lässt sich erfassen, sodass der Motor abgeschaltet werden kann, wenn er sich im Leerlauf befindet.

##### Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

##### Anwendbarkeit

Breiter Anwendungsbereich der Nahrungsmittelproduktion.

##### Wirtschaftliche Aspekte

Geringere Energiekosten.

##### Anlass für die Umsetzung

Geringere Energiekosten.

### Referenzliteratur

[69, Environment Agency of England and Wales, 2001]

#### **4.2.13.7 Verringerung der Belastung von Motoren**

##### Beschreibung

Motoren und Antriebe werden für den Betrieb vieler mechanischer Systeme in Industrieprozessen verwendet. Die Belastung von Motoren und Antrieben lässt sich verringern, wenn regelmäßige Überprüfungen und grundlegende Wartungsschritte wie beispielsweise das Schmieren mechanischer Teile durchgeführt werden.

Wenn die folgenden Punkte erfüllt sind, lässt sich die Motorbelastung minimieren:

- Arbeitet die vom Motor betriebene Maschine effizient?
- Erfüllt das System eine nützliche und notwendige Funktion?
- Ist die Übertragung zwischen Motor und angetriebenem Gerät effizient?
- Sind die Wartungsprogramme ausreichend?
- Sind Verluste, beispielsweise durch Rohrleitungen, Ableitungen und Isolierung, minimiert worden?
- Ist das Steuerungssystem effektiv?

##### Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

##### Anwendbarkeit

Anwendbar, wo Motoren eingesetzt werden.

##### Wirtschaftliche Aspekte

Geringere Energiekosten.

Anlass für die Umsetzung

Geringere Energiekosten.

Referenzliteratur

[69, Environment Agency of England and Wales, 2001]

**4.2.13.8 Reduzierung von Verlusten bei Motoren**Beschreibung

Verluste bei Motoren lassen sich durch folgende Maßnahmen minimieren:

- falls möglich, Einsatz effizienterer Motoren
- bei Versagen eines Motors Gewährleistung einer sorgfältigen und gründlichen Reparatur, sodass Energieverluste minimiert werden
- Vermeidung des Einsatzes stark überdimensionierter Motoren
- Erwägung einer dauerhaften Änderung der Stromversorgung des Motors in Sternschaltung, wodurch sich ohne Kosten die Verluste nur leicht belasteter Motoren senken lassen.
- Vermeidung übermäßiger Verluste durch Spannungsungleichgewichte, zu niedrige oder zu hohe Versorgungsspannungen, harmonische Verzerrungen oder einen schlechten Leistungsfaktor.

Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

Anwendbarkeit

Anwendbar, wo Motoren eingesetzt werden.

Wirtschaftliche Aspekte

Geringere Energiekosten.

Anlass für die Umsetzung

Geringere Energiekosten.

Referenzliteratur

[69, Environment Agency of England and Wales, 2001]

**4.2.13.9 Frequenzwandler bei Motoren**Beschreibung

Durch die Steuerung des Pumpenmotors über Frequenzwandler wird gewährleistet, dass die Laufradgeschwindigkeit genau an die erforderliche Pumpenleistung angepasst ist; das gilt auch für den Stromverbrauch und die Behandlung der Flüssigkeit.

Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

Betriebsdaten

Der Rückgang im Stromverbrauch hängt von Kapazität und Anzahl der Pumpen und Motoren ab. Im Allgemeinen entspricht eine Reduktion der Pumpenabgabeleistung um 10 % einem Rückgang um 28 % im Stromverbrauch der Pumpe.

In einer deutschen Beispielanlage eines Herstellers von löslichem Kaffee ermöglichte die Ausstattung aller großen Elektromotoren mit Frequenzwandlern eine immer bedarfsgerechte Einstellung, und Stromspitzen während des Hochfahrens konnten vermieden werden.

In einer dänischen Molkerei wurden 203 Motoren mit Frequenzwandlern ausgestattet. Die Gesamtleistung der Motoren betrug 1.216 kW. Die geschätzten Investitionskosten betragen 311.000 EUR. Die geschätzte jährliche Einsparung beträgt 90.000 EUR (1.325.000 kWh).

Ein Molkeprodukteunternehmen verarbeitet Molke zu verschiedenen Rohmaterialien, die in der Pharmazie und in der Nahrungsmittelindustrie Verwendung finden. Eines der Produkte ist Laktose, bei deren Herstellung ein

Raffinerieverfahren angewandt wird, in dem „nasse“ Laktose (Reinheit 9 %) in einem Kreislaufverfahren in Heißwasser aufgelöst wird. Die nasse Laktose wird durch eine Schüttelschale in ein Mischgefäß transportiert, wo sie mit heißem Wasser gemischt wird. Das Gemisch wird in ein Puffergefäß gepumpt; dort wird es gerührt und anschließend wieder ins Mischgefäß zurückgeleitet. So nimmt der Laktosegehalt des Gemischs allmählich zu. Nach etwa einer Stunde wird das Gemisch aus der Mischanlage zur weiteren Verarbeitung abgegeben. Der Flüssigkeitsstand im Mischgefäß wurde früher durch die Regulierung des Wasser-/Laktosezustroms aus den Puffertanks geregelt. Dies wurde mit einem Drosselventil auf der Abgabeseite der für den Transport verwendeten Kreiselpumpe erreicht. Das Drosselsystem hatte mehrere Nachteile; beispielsweise war es ineffizient und verursachte einen unnötigen Verbrauch elektrischer Energie sowie eine unnötige Abnutzung der Pumpe. Es wurde durch eine Drehzahlsteuerung am Pumpenmotor ersetzt. Daraus ergaben sich Energieeinsparungen von 12.600 kWh/Jahr im Wert von 1638 NLG (1994) sowie ein Rückgang der Wartungskosten in Höhe von 10.257 NLG/Jahr (1994), und eine Amortisationsdauer von 0,3 Jahren.

In einer Beispielbrauerei wird von sechs Schrauben- und sieben Kolbenverdichtern Druckluft (6 bar) erzeugt. Einer der Schraubenverdichter wird als frequenzgesteuerte Maschine betrieben, und alle Verdichter werden zentral gesteuert. Der Vorteil dieser Technik besteht darin, dass der Druck im Versorgungssystem nicht um mehr als +/- 0,05 bar schwankt. Der Systemdruck kann um 0,2 bar gesenkt werden. Angaben zufolge lässt sich durch das Vermeiden von Leerlaufzeiten bei Verdichtern eine Stromersparnis von etwa 20 % erzielen. Die Wartungskosten lassen sich um etwa 15 % senken. Der Kostennutzen, der sich aus der Reduktion des Systemdrucks ergibt, ist nicht quantifizierbar.

### Anwendbarkeit

Bei normalen Dreiphasenmotoren können Frequenzwandler verwendet werden. Sie sind sowohl für manuelle als auch automatische Drehzahlsteuerung erhältlich. Sie lassen sich in bestehenden und neuen Anlagen für Pumpen, Belüftungsgeräte und Transportsysteme installieren. Angaben zufolge sollten mit Frequenzwandlern betriebene Motoren nicht mehr als 60 % der Gesamtenergie der Anlage verbrauchen, da sie die Stromversorgung beeinträchtigen und zu technischen Problemen führen können.

### Wirtschaftliche Aspekte

Der Preis eines 5,5-kW-Frequenzwandlers beträgt etwa 600 EUR.

### Anlass für die Umsetzung

Geringerer Stromverbrauch und gleichzeitig sanftere Behandlung des Produkts.

### Beispielanlagen

Eine Molkerei in Dänemark, ein Molkehersteller in den Niederlanden, ein Hersteller von löslichem Kaffee in Deutschland und eine Brauerei in Deutschland.

### Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001, 65, Germany, 2002, 237, Caddet, 1999, 247, Verband der Deutschen Milchwirtschaft (German Dairy Association), 2003]

## **4.2.13.10 Einsatz von Verstellgetrieben zur Verringerung der Belastung von Ventilatoren und Pumpen**

### Beschreibung

Insbesondere die Antriebskraft kann einen erheblichen Anteil am Energieverbrauch in Industrieprozessen haben. Die Investitionskosten für einen Motor mit größerer Effizienz sind nicht höher als für einen normalen Motor, aber die Effizienzsteigerung um 2 - 3 % erbringt im Laufe der Lebensdauer des Motors erhebliche Einsparungen. Außerdem lassen sich Stoffströme durch Verstellgetriebe zur Verringerung der Belastung von Ventilatoren und Pumpen deutlich energieeffizienter regulieren als durch Drossel-, Dämpfungs- und Rezirkulationssysteme.

### Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion, in denen Ventilatoren und Pumpen eingesetzt werden.

Wirtschaftliche Aspekte  
Geringere Energiekosten.

Anlass für die Umsetzung  
Geringere Energiekosten.

Referenzliteratur  
[69, Environment Agency of England and Wales, 2001]

## **4.2.14 Verwendung von Wasser**

### **4.2.14.1 Nicht mehr Wasser fördern als nötig**

Beschreibung  
Wenn nur die tatsächlich für den Produktionsprozess erforderlichen Wassermengen hochgepumpt werden, minimieren sich die Auswirkungen auf den Grundwasserspiegel und es wird Energie gespart. Es sollte nur bei Bedarf Wasser gefördert werden, sodass übermäßige Lagerung und damit das Risiko von Wasserverlusten durch Kontaminationen oder Auslaufen verhindert wird.

Erreichbare Umweltvorteile  
Geringerer Wasser- und Energieverbrauch.

Anwendbarkeit  
Anwendbar in Bereichen, in denen Grundwasser gefördert wird.

Anlass für die Umsetzung  
Lokale Grundwasserknappheit.

Beispielanlagen  
Obst- und Gemüseanlagen in Belgien.

Referenzliteratur  
[31, VITO, et al., 2001]

## **4.2.15 Kühlung und Klimatisierung**

(Siehe 4.2.11 für verwandte Tiefkühltechniken)

### **4.2.15.1 Optimierung der Temperatur bei der Klimatisierung und in Kühllagern**

Beschreibung  
Wenn klimatisierte Räume und Kühllager nicht stärker als nötig gekühlt werden, sinkt der Energieverbrauch, ohne dass die Nahrungsmittelqualität beeinträchtigt wird. Kaltlagerbereiche werden aus Furcht vor Ausfällen oft kälter gehalten als nötig. Wird ein Kaltlagerbereich kälter als nötig gehalten, steigt die Wahrscheinlichkeit eines Ausfalls.

Berichten zufolge kann die einfache Gestaltung von Steuerelementen und deren richtige Einstellung viel zu einem möglichst effizienten Betrieb der Kühlanlage beitragen, z. B. indem der Thermostat so eingestellt wird, dass ohne Beeinträchtigung der Zuverlässigkeit die beste Energieeffizienz erzielt wird. Durch das Markieren von Normalwerten an Messgeräten lassen sich Fehler an den Maschinen und Ausrüstungen früher erkennen. Kühlanlage und/oder Beleuchtung können durch automatische Steuerungen abgeschaltet werden, wenn sie nicht benötigt werden. Beleuchtung und Motoren in gekühlten Bereichen verbrauchen nicht nur Strom, sondern erzeugen auch Wärme und erhöhen so den Bedarf an Kühlenergie. Falls sie gar nicht benötigt werden, können sie entfernt und ansonsten bei Nichtgebrauch ausgeschaltet werden, um Energie zu sparen.

Erreichbare Umweltvorteile  
Geringerer Energieverbrauch.

### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion, die über klimatisierte Bereiche und Kühlgeräte verfügen.

### Anlass für die Umsetzung

Geringere Energiekosten.

### Referenzliteratur

[69, Environment Agency of England and Wales, 2001, 241, ETSU, 2000]

#### **4.2.15.2 Minimierung von Transmissions- und Ventilationsverlusten aus gekühlten Räumen, Kühllagern und Gefriertunneln**

### Beschreibung

Die folgenden Maßnahmen können zur Verringerung von Transmissions- und Ventilationsverlusten im Tiefkühlbereich ergriffen werden:

- Türen und Fenster möglichst geschlossen halten
- zwischen Bereichen mit unterschiedlicher Temperatur schnellschließende und gut isolierende Türen einbauen
- Türgröße auf das für einen sicheren Zugang notwendige Minimum beschränken
- auf gute Abdichtung von Türöffnungen achten; Eisablagerungen an Öffnungen deuten auf schlechte Abdichtung hin
- Material nicht in der Türöffnung verladen
- den Bereich vor dem Kühlraum kühlen
- Türen, die häufig geöffnet werden müssen, mit Streifenvorhängen ausstatten
- Luftaustausch begrenzen, indem der Übergang zwischen dem Be-/Entladebereich des Fahrzeugs und dem Lagerbereich gut abgedichtet wird
- Luftbewegung bei geöffneten Türen und Klappen einschränken
- bei Gefriertunneln auf angemessene thermische Isolierung und Abschirmung gegenüber der Umgebung achten
- Kühlvorgänge bei Nacht durchführen, wenn die Umgebungstemperaturen am geringsten sind.

### Erreichbare Umweltvorteile

Geringerer Energieverbrauch. In manchen Fällen lassen sich auch Geruchs- und Lärmemissionen senken.

### Anwendbarkeit

Beim Tiefkühlen verpackter und unverpackter Lebensmittelprodukte und in klimatisierten Räumen praktiziert.

### Wirtschaftliche Aspekte

Für 2001 liegt die Angabe vor, dass die Kosten, die durch eine geöffnete Tür verursacht wurden, in einem Tiefkühlager 6 GBP/Stunde und in einem Kühllager von 3 GBP/Stunde betragen.

### Referenzliteratur

[31, VITO, et al., 2001, 32, Van Bael J., 1998, 69, Environment Agency of England and Wales, 2001]

#### **4.2.15.3 Regelmäßiges Abtauen des gesamten Systems**

### Beschreibung

Bei weniger als 0 °C betriebene Verdampfer sollten vollständig entfrosten werden, bevor das Eis beginnt, die Rippen zu bedecken. Das kann im Abstand von einigen Stunden oder einigen Tagen der Fall sein. Wenn der Verdampfer vereist ist, sinkt die Verdampfungstemperatur und der Energieverbrauch steigt. Außerdem sinkt die Kapazität, und es wird möglicherweise nicht auf die erforderliche Temperatur heruntergekühlt. Wenn die Entfroster Elemente nicht ordnungsgemäß funktionieren, erhöht sich die Frostanreicherung auf dem Verdampfer. Aus diesem Grund ist die Überprüfung des ordnungsgemäßen Abtauens von Verdampfern wichtig. In Abschnitt 4.2.15.5 wird das automatische Abtauen von Kühlverdampfern beschrieben.

Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

Betriebsdaten

Ein Absinken der Verdampfungstemperatur um 1 °C kann zu einer Erhöhung der Betriebskosten um 2 - 4 % führen. Mit Entfrostsungssystemen, die eine Entfrostsung nicht automatisch, sondern nur bei Bedarf einleiten, wurde Berichten zufolge bei manchen Anwendungen der Stromverbrauch um 30 % gesenkt.

Anwendbarkeit

Wird in der Tiefkühlung und Kühlung verpackter und unverpackter Lebensmittelprodukte eingesetzt.

Referenzliteratur

[31, VITO, et al., 2001, 32, Van Bael J., 1998]

**4.2.15.4 Optimierung des Abtauzyklus**Beschreibung

Zur Optimierung des Abtauzyklus von Verdampfern kann der zeitliche Abstand zwischen den Zyklen angepasst werden. Wenn der Zeitraum zwischen zwei Abtauzyklen zu lang ist, nimmt die Verdampfeffizienz ab und der Druck sinkt über den Verdampfer. Wenn der Zeitraum zu kurz ist, wird im Lagerbereich unnötigerweise eine erhebliche Wärmemenge erzeugt.

Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

Anwendbarkeit

Angewendet beim Tiefkühlen verpackter und unverpackter Lebensmittelprodukte.

Referenzliteratur

[31, VITO, et al., 2001, 32, Van Bael J., 1998]

**4.2.15.5 Automatisches Abtauen von Kühlverdampfern in Kaltlagerbereichen**Beschreibung

Die Frostsicht, die sich auf der Verdampferoberfläche bildet, mindert die Wärmeaustauscheffizienz des Gerätes. Warmes Gas vom Kompressor kann zum Abtauen und Entfernen dieser Schicht verwendet werden. Die so erzielte Energieeinsparung hängt von der Kapazität/Anzahl der Verdampfer und der Betriebsdauer der vereisten Verdampfer ab.

Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

Betriebsdaten

In einer Speiseeisanlage wurden fünf Verdampfer, die jährlich 3.000 Stunden mit einer Eisschicht von 0,87 mm betrieben wurden, mit einem automatischen Abtausystem ausgestattet. Dadurch konnten etwa 100.000 kWh/Jahr an Energie gespart werden. Die geschätzten Investitionskosten betragen 15.000 EUR bei einer Amortisationsdauer von 2,2 Jahren.

Anwendbarkeit

In neuen Anlagen weit verbreitet und bei bestehenden Anlagen leicht anzuwenden.

Wirtschaftliche Aspekte

Geringere Energiekosten. Kurze Amortisationszeiten.

Beispielanlagen

Eine Speiseeisanlage in einem nordeuropäischen Land.

Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001]

**4.2.15.6 Verwendung von Binäreis als Kühlflüssigkeit (sekundäres Kältemittel)**

Beschreibung

Binäreis kann als Kühlflüssigkeit verwendet werden. Binäreis lässt sich als „flüssiges Eis“ beschreiben. Es besteht aus einer Suspension von Eiskristallen mit einer Größe von 10 – 100 µm in mit Frostschutzmittel versetztem Wasser. Das Frostschutzmittel ist entweder ein Korrosionsschutzmittel enthaltendes Produkt auf Ethanolbasis, oder, wenn Nahrungsmittel in das Binäreis eingetaucht werden sollen, gewöhnliches Salz (Natriumchlorid).

Es gibt zwei Technologien zur Herstellung von Binäreis. Die erste ist in Abbildung 4.20 dargestellt und für Binäreis mit geringer bis mittlerer Kapazität, also 100 – 1.000 kW, geeignet. Die Ziffern im folgenden Text beziehen sich auf Abbildung 4.20. Das Binäreis wird mit einem speziellen Verdampfer, einem sogenannten Binäreis-Generator (1), erzeugt, der über eine Pumpe (2) mit Flüssigkeit aus einem Binäreis-Vorratsgefäß (3) versorgt wird. Eine herkömmliche Kühlanlage (4) mit kleiner Kältemittelladung wird an den Binäreis-Generator angeschlossen. Als Alternativen zu Fluorchlorkohlenwasserstoffen können "natürliche" Kältemittel wie Wasser (nicht zum Gefrieren), Luft, Kohlendioxid (noch in der Entwicklung), Ammoniak und Kohlenwasserstoffe verwendet werden. Eine Sekundärpumpe (5) versorgt die Hauptzufuhrleitung (6) mit Binäreis in der vorgegebenen Eiskonzentration. Von dort verteilen (fakultative) Pumpen (7) das Binäreis an die Kühllasten (8). Im Falle einer „Nulllast“, aber im Bereitschaftsmodus, wird das Binäreis weiterhin durch die Sekundärschleife (6 und 10) zirkuliert, passiert jedoch das Ventil (9), das sich öffnet, sobald die Kühllasten vom System getrennt werden. Die Rückführleitung (10) bringt die Binäreis-Flüssigkeit (mit Eiskristallen oder ohne) in den Vorratsbehälter (3) zurück.

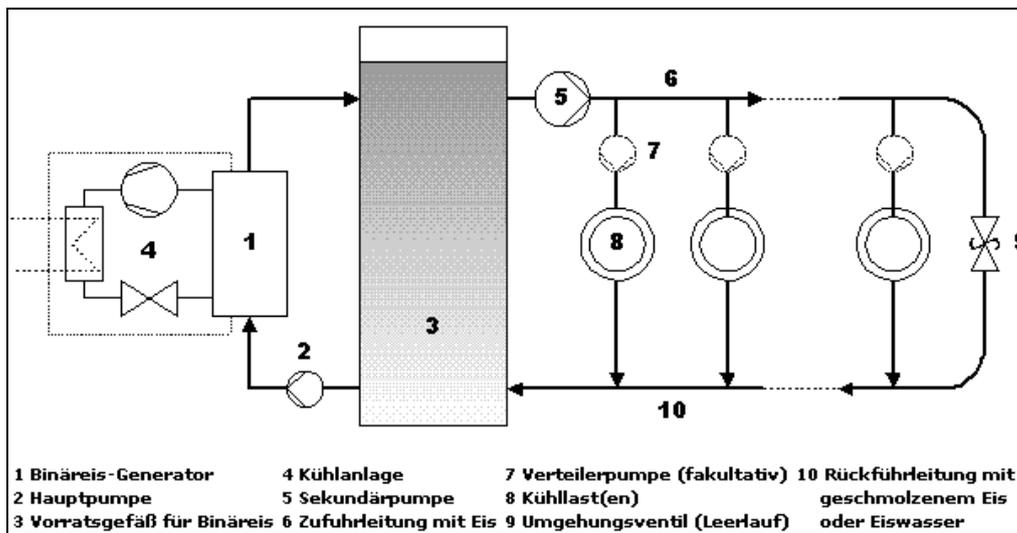


Abbildung 4.20: Binäreis-System mit konventioneller Kühlanlage

Mittlere und große Kapazitäten von Binäreis, also von 1.000 kW - 1 MW, können ebenfalls mit einem Kühlprozess mit „Wasser als Kältemittel“ hergestellt werden. Das Verfahren ähnelt dem in Abbildung 4.20 dargestellten, jedoch ist die konventionelle Kühlanlage (4) nicht erforderlich. Ein Wasserdampfkompresor und geeignete Vakuumbedingungen (bei Binäreis üblicherweise 500 Pa bzw. 5 mbar) lassen das Wasser in einem leeren Gefäß (Verdampfer) verdampfen, und der Kompressor entfernt den Wasserdampf, der schließlich kondensiert wird.

Erreichbare Umweltvorteile

Unter vergleichbaren Bedingungen ist der Leistungskoeffizient für Binäreis normalerweise besser als für herkömmliche Kühl- und Gefrieranlagen, d. h. es wird weniger Strom verbraucht. Es werden kleinere Kühleinheiten benötigt, sodass weniger Material gebraucht wird. Da diese nicht so chemikalienresistent sein müssen, können sie einfacher und besser für die Wiederverwertung geeignet sein. Da die gesamte Anlage nicht mit potenziell schädlichen Kältemitteln gefüllt ist, verringern sich Wahrscheinlichkeit und Schweregrad einer unbeabsichtigten Freisetzung. Im Unterschied zu anderen Kältemitteln kann aus Alkohol und Wasser hergestelltes Binäreis normalerweise in die Kläranlage abgegeben werden, sofern die entsprechende Genehmigung vorliegt. Die Eigenschaften des schnellen Phasenwechsels von Eiskristallen sorgen angabegemäß

für ausgezeichnete Wärmeübertragung. Daher kann entweder die Oberfläche verkleinert werden, oder das Binäreis kann „wärmer“ sein, was zu einem geringeren Energiebedarf und zu weniger Einfrieren der Oberfläche führt. Damit ist der Gewichtsschwund des Produktes geringer, und bei Luftkühlern wird möglicherweise sogar das Entfrostn überflüssig. Flüssigkühler können ebenfalls 20 bis 50 % kleiner ausfallen.

#### Betriebsdaten

Tabelle 4.6 vergleicht die Volumina der Kältemittel Sole und Binäreis, die für die Erzielung einer Temperaturabnahme um 3 °C erforderlich sind.

| Kühlvorgang | Kältemittel                     | Vergleichbare Kühlfähigkeit für eine gegebene Masse zur Erzielung einer Temperaturabnahme um 3 °C | Für die Kühlung verfügbare Energie (kJ/kg) |
|-------------|---------------------------------|---|--|
| Kühlen      | Sole                            | 1   | 11   |
|             | Binäreis mit 10 % Eiskristallen | 3,0   | 33   |
|             | Binäreis mit 20 % Eiskristallen | 6,0   | 66   |
| Tiefkühlen  | Sole                            | 1   | 11   |
|             | Binäreis mit 10 % Eiskristallen | 3,7   | 33   |
|             | Binäreis mit 20 % Eiskristallen | 7,3   | 66   |

**Tabelle 4.22: Vergleich der Volumina von Binäreis und Sole, die zur Erzielung einer Temperaturabsenkung um 3 °C erforderlich sind**

So muss beispielsweise vier- bis siebenmal mehr Kältemittel zirkuliert werden, wenn Sole anstatt Binäreis als Kältemittel verwendet wird. Angabegemäß können bei der Verwendung von Binäreis gegenüber Sole die Rohrdurchmesser ungefähr 50 % kleiner und die Pumpleistung 70 % geringer sein. Es wird außerdem berichtet, dass Binäreis-Anlagen üblicherweise 24 Stunden am Tag laufen, sodass nur eine kleine Eismaschine und geringes Lagervolumen erforderlich sind.

In einer hier als Beispiel genannten Tierschlacht- und Fleischverarbeitungsanlage wurden die Rinder- und Schweineschlachtkörper vor der Weiterverarbeitung gekühlt. Die folgende Binäreis-Anlage mit einer Installationsgesamtkapazität von 424 kW wurde für die in Tabelle 4.23 angegebene erforderliche Kühlleistung installiert:

|   |                               |
|---|-------------------------------|
| Genutzte Fläche insgesamt                                 | 3.800 m <sup>2</sup>          |
| Anzahl der Angestellten                                   | 40                            |
| Wochenproduktion  | 500 Rinder und 2.000 Schweine |
| Kältemittel   | Ammoniak                      |
| Binäreis-System   | Handelsname                   |
| Anzahl der unabhängigen Kühlanlagen                       | 2                             |
| Kompressoren  | Gram (Kolbenverdichter)       |
| Weitere Merkmale  | Wärmerückgewinnung            |
| Kühlleistung pro Tag                                      | 5.500 kWh/d                   |
| Betriebsstunden bei voller Auslastung (maximal)           | 13 h/d                        |
| Installierte Kühlkapazität (Eismaschinen)                 | 230 kW                        |
| Betriebsstunden der Binäreis-Anlage (heißester Sommertag) | 24 h/d                        |
| Binäreis-Lagerleistung                                    | 1.600 kWh                     |
| Binäreis-Lagervolumen                                     | 34 m <sup>3</sup>             |
| Binäreis-Flüssigkorrosionsschutz                          | Handelsname                   |
| Maximale Binäreis-Konzentration im Eislager               | >50 %                         |
| Binäreis-Konzentration in den Leitungen                   | 12 %                          |

**Tabelle 4.23: Erforderliche Kühlleistung einer Binäreis-Anlage**

### Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

### Wirtschaftliche Aspekte

Im oben beschriebenen Beispiel einer Schlacht- und Fleischverarbeitungsanlage betrug die Lebensdauer 15 Jahre. Bei einem Zinssatz von 7 % und einer Abschreibungsdauer von 10 Jahren wurden die zusätzlichen direkten Investitionskosten den Angaben zufolge in 2,2 Jahren eingespart, und die jährlichen Betriebskosten der Binäreis-Anlage einschließlich der Abschreibungskosten waren sofort einsparbar. Für typische dänische Schachtanlagen wird die Amortisationsdauer auf 10 bis 15 Jahre geschätzt.

Angaben zufolge werden Binäreis-Anlagen normalerweise zu einem anderen als dem Spitzentarif oder zu Zeiten eines insgesamt niedrigen Stromverbrauchs betrieben.

### Anlass für die Umsetzung

Das graduelle Verbot der Verwendung ozonabbauender Fluorchlorkohlenwasserstoffe gemäß „Montreal-Protokoll“ und der erwartete Druck hinsichtlich der Verbrauchsminderung von Fluorkohlenwasserstoffen durch das Kyoto-Protokoll.

### Beispielanlagen

Wird in der Fleischverarbeitung, der Fischverarbeitung, in Brauereien und in Kühllagern in Deutschland eingesetzt.

### Referenzliteratur

[182, Germany, 2003]

## **4.2.16 Erzeugung und Verwendung von Druckluft**

### **4.2.16.1 Optimierung der Druckeinstellungen**

#### Beschreibung

Der Druck am Kompressor kann auf das erforderliche Maximum eingestellt und dann bei jeder einzelnen Anwendung entsprechend reguliert werden, um den Energiebedarf für die Erzeugung von Druckluft sowie Leckagen zu verringern. Es kann energie- und kosteneffizienter sein, für einzelne Anwendungen, die höhere Drücke oder längere Betriebszeiten als die meisten anderen Druckluftanwendungen erfordern, einen eigenen Kompressor zu installieren.

#### Erreichbare Umweltvorteile

Geringerer Energieverbrauch und weniger Lärm, wenn große Kompressoren über kürzere Zeiträume laufen.

#### Anwendbarkeit

Anwendbar, wo es mehr als einen Verwendungszweck für Druckluft in einer Anlage gibt.

#### Anlass für die Umsetzung

Geringerer Energieverbrauch und damit geringere Kosten.

#### Beispielanlagen

Weit verbreitet.

#### Referenzliteratur

[69, Environment Agency of England and Wales, 2001]

### **4.2.16.2 Optimierung der Temperatur der zugeführten Luft**

#### Beschreibung

Kompressoren arbeiten mit kühler Luft effizienter. Das wird im Allgemeinen dadurch erreicht, dass Luft von außerhalb des Gebäudes verwendet wird. Überprüft werden kann dies durch die Messung der Trockner-Zulufttemperatur, die bei voller Auslastung der Kompressoren nicht mehr als 35 °C betragen sollte. Die Temperatur

des Trockerraums sollte nicht mehr als 5 °C über der Außenumgebungstemperatur liegen. Wenn die Raumtemperatur zu hoch ist, wird die Kompressorleistung gemindert.

#### Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

#### Anlass für die Umsetzung

Geringerer Energieverbrauch und damit geringere Kosten.

#### Referenzliteratur

[69, Environment Agency of England and Wales, 2001]

### **4.2.16.3 Ausstattung von Luftein- und -auslässen mit Schalldämpfern**

#### Beschreibung

An der Luftzufuhr oder der Abluftöffnung des Kompressors Schalldämpfer anbringen. Schalldämpfer können absorptiv oder reaktiv sein. Absorptive Schalldämpfer absorbieren den Lärm. Reaktive Schalldämpfer enthalten Kammern und Schallwände, deren Größe und Position ihre Schalldämpfungseigenschaften bestimmen. Reaktive Schalldämpfer sind für Kompressoren, die starken niederfrequenten Lärm erzeugen, möglicherweise effektiver.

#### Erreichbare Umweltvorteile

Verringerte Lärmemissionen.

#### Medienübergreifende Effekte

Wenn der Schalldämpfer nicht richtig konzipiert ist, kann er den Energieverbrauch durch Gegendruck oder Blockaden erhöhen.

#### Betriebsdaten

Angaben zufolge erhöht ein richtig konzipierter Schalldämpfer den Gegendruck im System nicht. Wenn der Schalldämpfer nicht richtig konzipiert ist, kann eine stärkere Dämpfung zu einem erhöhten Druckabfall und damit zu einem erhöhten Energieverbrauch führen. Der Gegendruck lässt sich durch Vergrößern des Schalldämpfers und die Kopplung zwischen Schalldämpfer und Kompressor minimieren. Durch Einbau eines Absorptionsschalldämpfers können sowohl Gegendruck als auch Blockaden vermieden werden.

Angaben zufolge können mehrere Abluftleitungen an eine Sammelleitung angeschlossen werden, die dann in ein einziges Rohr mit größerer Öffnung übergeht. Angabegemäß ist der hintere Schalldämpfer praktisch jedes Automodells dazu geeignet, eine Reduktion um 25 dB(A) zu erzielen.

#### Anwendbarkeit

Anwendbar bei der Verwendung von Druckluft.

#### Wirtschaftliche Aspekte

Geringe Kosten.

#### Anlass für die Umsetzung

Vorbeugung gegen durch Lärm am Arbeitsplatz bedingte Gehörschäden und weniger Beschwerden über Lärmemissionen von außerhalb der Anlage.

#### Beispielanlagen

Weit verbreitet.

#### Referenzliteratur

[65, Germany, 2002, 200, CIAA, 2003, 242, Lewis D. N., 2003, 244, Health and Safety Executive, ]

### 4.2.17 Dampfsysteme

#### 4.2.17.1 Maximierung der Kondensatrückführung

##### Beschreibung

Wenn heißes Kondensat nicht zum Kessel zurückgeführt wird, muss es durch behandeltes kaltes Zusatzwasser ersetzt werden. Das zusätzliche Wasser erhöht ebenfalls die Wasserbehandlungskosten. Anstatt das Kondensat wegen des Kontaminationsrisikos routinemäßig in die Kläranlage einzuleiten, kann man es in einem Zwischentank auffangen und auf vorhandene Kontaminationen untersuchen. Dadurch lassen sich auch Einsparungen beim Einsatz von Chemikalien zur Behandlung des Kesselspeisewassers erzielen. Zusätzlich oder als Alternative, falls das Kondensat wegen Kontamination nicht zum Kessel zurückgeführt werden kann, lässt sich aus dem kontaminierten Kondensat Wärme rückgewinnen, bevor es für minderwertige Reinigungsarbeiten, z. B. für die Hofreinigung, verwendet wird.

Energie aus Dampf, der direkt in den Prozess injiziert wird, kann als vollständig genutzt gelten.

##### Erreichbare Umweltvorteile

Geringerer Energie- und Wasserverbrauch und weniger Abfall. Geringerer Verbrauch an Chemikalien zur Behandlung des Kesselspeisewassers.

##### Betriebsdaten

Wenn heißes Kondensat nicht zum Kessel zurückgeführt wird, muss es durch behandeltes kaltes Zusatzwasser ersetzt werden, und es gehen etwa 20 % der Energie verloren, die absorbiert wurde bei der Erzeugung des Dampfes, aus dem das Kondensat stammt. Das ist unter Umständen der größte Energieverlust beim Dampfeinsatz.

##### Anwendbarkeit

Anwendbar, wenn Dampf in einem Kessel produziert wird.

##### Anlass für die Umsetzung

Geringerer Energieverbrauch und damit geringere Kosten.

##### Referenzliteratur

[69, Environment Agency of England and Wales, 2001]

#### 4.2.17.2 Vermeidung der Verluste von Entspannungsdampf aus der Kondensatrückführung

##### Beschreibung

Wenn Kondensat aus Kondensattöpfen abgegeben wird und durch die Rückführleitungen fließt, bildet sich etwas Entspannungsdampf. Oft wird der Entspannungsdampf an die Luft abgegeben, und die darin enthaltene Energie geht verloren. Es kann möglich sein, den Entspannungsdampf aufzufangen und zu verwenden, z. B. im Kessel.

##### Erreichbare Umweltvorteile

Geringerer Energie- und Wasserverbrauch.

##### Betriebsdaten

Der Entspannungsdampf enthält normalerweise etwa 40 % der Energie, die sich im ursprünglichen, unter Druck stehenden Kondensat befand.

##### Anwendbarkeit

Anwendbar, wenn Entspannungsdampf entsteht und wieder verwendet werden kann.

##### Anlass für die Umsetzung

Geringerer Energieverbrauch und damit geringere Kosten.

##### Referenzliteratur

[69, Environment Agency of England and Wales, 2001]

### 4.2.17.3 Abtrennung von selten oder gar nicht verwendeten Rohrleitungen

#### Beschreibung

Möglicherweise gibt es Zweige des Dampfverteilersystems, die nicht mehr verwendet werden und vom System getrennt werden können. Auch können Rohrleitungen, die selten verwendete Geräte mit Dampf versorgen, mit Ventilen oder Schiebern vom restlichen System isoliert werden. Nicht und selten genutzte Rohrleitungen verursachen einen unnötigen Energieverbrauch und werden wahrscheinlich unzureichend gewartet. Werden Rohrleitungen entfernt, kann es sein, dass die verbleibenden Leitungen nicht mehr ausreichend gestützt werden und zusätzliche Verstrebungen erfordern.

#### Erreichbare Umweltvorteile

Geringerer Energie- und Wasserverbrauch.

#### Anwendbarkeit

Ohne Einschränkung anwendbar.

#### Anlass für die Umsetzung

Geringerer Energieverbrauch und damit geringere Kosten.

#### Referenzliteratur

[69, Environment Agency of England and Wales, 2001]

### 4.2.17.4 Minimierung des Abblasens von Kesseln

#### Beschreibung

Das Abblasen eines Kessels dient dazu, die Anreicherung von Salzen, z. B. Chloriden, Alkalien und Kieselsäure, zu begrenzen und ist daher notwendig, um diese Parameter innerhalb der vorgeschriebenen Grenzen zu halten. Außerdem wird es dazu genutzt, um Schlammablagerungen wie Calciumphosphate und Korrosionsprodukte wie Eisenoxide aus dem Kessel zu entfernen und das Wasser klar und farblos zu halten. Dabei wird immer Abwasser mit hohem Druck und hoher Temperatur abgegeben, entweder für eine bestimmte Zeit oder fortlaufend. Daher ist es ratsam, das Abblasen so weit wie möglich zu begrenzen.

Der Gesamtgehalt gelöster Schwebstoffe im Kesselwasser wird am besten so dicht wie möglich am zulässigen Höchstwert gehalten. Das kann über ein automatisches System erfolgen, das aus einer Leitfähigkeitssonde im Kesselwasser, einem Abblasregler oder einem Regulierventil für das Abblasen besteht. Die Leitfähigkeit wird kontinuierlich gemessen. Wenn die gemessene Leitfähigkeit den Höchstwert überschreitet, wird das Regulierventil weiter geöffnet.

Zur Senkung des Energieverbrauchs kann Wärme vom Abblasen des Kessels rückgewonnen werden.

#### Erreichbare Umweltvorteile

Geringerer Energieverbrauch. Geringere Abwassermenge.

#### Betriebsdaten

In Tabelle 4.24 sind die potenziellen Brennstoffeinsparungen angegeben, die sich durch eine Reduzierung des Abblasens in Abhängigkeit vom Dampfdruck beim Tiefkühlen von Gemüse erzielen lassen. Bei einem Dampfdruck von 10 bar kann eine Brennstoffersparnis von 2,1 % erzielt werden, wenn das Abblasvolumen um 10 % verringert wird.

| Effektiver Kesseldruck<br>(bar) | Brennstoffeinsparung pro<br>Abblasreduzierung<br>(%) |
|---------------------------------|--|
| 7                               | 0,19   |
| 10                              | 0,21   |
| 17                              | 0,25   |

Tabelle 4.24: Potenzielle Einsparungen durch die Reduzierung des Kesselabblasens beim Tiefkühlen von Gemüse

#### Anwendbarkeit

Anwendbar, wenn ein Kessel verwendet wird.

### Referenzliteratur

[31, VITO, et al., 2001, 32, Van Bael J., 1998]

## 4.3 Reinigung

Prozessgeräte und Produktionsanlagen werden regelmäßig gereinigt und desinfiziert, wobei die Häufigkeit von Produkt zu Produkt und von Prozess zu Prozess unterschiedlich ist. Ziel von Reinigung und Desinfektion ist die Beseitigung von Produktrückständen aus dem vorhergehenden Prozess, von anderen Kontaminationen und Mikroorganismen zur Gewährleistung der Produktqualität, der Lebensmittelsicherheit, der Kapazität der Produktionslinie, der Wärmeübertragung und des optimalen Betriebs der Geräte. Sie können manuell, z. B. durch Druckreinigung, oder automatisch, z. B. als CIP-Reinigung, durchgeführt werden. Beim manuellen Reinigen ist im Allgemeinen die Demontage der zu reinigenden Geräte erforderlich.

### 4.3.1 Trockene Reinigung von Geräten und Anlagen

Einige sektorspezifische Beispiele finden sich auch in den Abschnitten 4.7.1.2, 4.7.2.2, 4.7.5.2 und 4.7.9.2.

#### Beschreibung

Vor der Nassreinigung kann so viel Rückstandsmaterial wie möglich aus Gefäßen, Geräten und Anlagen beseitigt werden, und zwar sowohl während der Arbeitszeit als auch bei Arbeitsschluss. Sämtliche Verschüttungen können, anstatt per Schlauch in den Ablauf gespült zu werden, aufgenommen werden, z. B. durch Aufschaukeln oder Aufsaugen verschütteten Materials oder durch Verwendung eines Gummischrubbers vor der Nassreinigung. Dadurch verringert sich die ins Wasser eingetragene Materialmenge, die entweder in der betriebseigenen oder in der kommunalen Kläranlage behandelt werden müsste. Die Situation lässt sich weiter verbessern, indem Material wie Inhaltsstoffe, Nebenprodukte und Abfälle so trocken wie möglich vom Verarbeitungsort abtransportiert werden (siehe Abschnitt 4.1.7.4).

Die trockene Reinigung wird z. B. durch die Bereitstellung und Verwendung von Filtereinsätzen (siehe Abschnitt 4.3.1.1) mit einer Siebabdeckung erleichtert, und auch durch die Bereitstellung von Trockenreinigungsgeräten, die leicht zugänglich sind, sowie von sicheren, gut erreichbaren Gefäßen für die aufgenommenen Abfälle. Filtereinsätze können verriegelt werden, sodass sie beim Reinigen nicht verrutschen.

Neben der manuellen Trockenreinigung von Geräten und Anlagen können auch andere Maßnahmen genutzt werden, wie beispielsweise das natürliche, durch die Schwerkraft bedingte Abfließen von Material in entsprechend positionierte Behältnisse oder die Verwendung von Molchsystemen (siehe Abschnitt 4.3.3).

Das Reinigungsverfahren kann so organisiert werden, dass die Nassreinigung bei gleichzeitiger Einhaltung der erforderlichen Hygienestandards minimiert wird. Z. B. kann der Einsatz von Schläuchen erst nach der Trockenreinigung gestattet werden.

#### Erreichbare Umweltvorteile

Verringerung von Wasserverbrauch und Abwasservolumen. Geringerer Eintrag von Stoffen ins Abwasser und dadurch geringere CSB- und BSB-Werte. Bessere Möglichkeiten zur Wiedergewinnung und Wiederverwertung von im Prozess erzeugten Substanzen. Geringerer Energieverbrauch für die Erwärmung von Reinigungswasser. Geringerer Verbrauch von Reinigungsmitteln.

#### Medienübergreifende Effekte

Mehr fester Abfall.

#### Betriebsdaten

Es ist gängige Praxis des Reinigungspersonals, Gitterroste von Bodenabläufen zu entfernen und Rohmaterial und Produkte direkt mit dem Schlauch in den Ablauf zu spülen, möglicherweise in der Annahme, dass ein Sieb oder Filtereinsatz an nachgelagerter Stelle alle Feststoffe auffängt. Sobald diese Stoffe jedoch in den Abwasserstrom gelangen, werden sie Turbulenzen, Pumpen und mechanischen Sieben ausgesetzt, wodurch sie abgebaut werden und löslicher BSB zusammen mit kolloidalen und möglicherweise suspendierten Fetten freigesetzt werden. Die spätere Entfernung dieser löslichen, kolloidalen und suspendierten organischen Stoffe kann viel komplizierter und teurer sein als die Verwendung einfacher Filtereinsätze mit Siebabdeckungen.

So können beispielsweise bei der Wurstherstellung Hackfleischrückstände aus Geräten wie Kuttern und Wurstfüllmaschinen sowie von Fußböden, soweit praktikabel, vor der Reinigung manuell beseitigt und z. B. an eine Anlage zur Verwertung tierischer Nebenprodukte weitergegeben anstatt in die Kläranlage gespült zu werden.

In einer Beispielanlage für die Fischverarbeitung wurden Transportbänder trocken gereinigt, sodass weniger Abfall entstand und die Wasserverschmutzung fast vollständig vermieden wurde.

Bei der Obst- und Gemüseverarbeitung können Produktverluste während des Prozesses aufgeschaufelt und zur Verwendung als Tierfutter abtransportiert werden.

Getreidestaub kann durch Vakuumsysteme aufgefangen werden, z. B. in Mehl- und Tierfuttermühlen, Brauereien und Brennereien.

Wenn staubförmiger Schmutz entfernt werden soll, so ist es wichtig, dass das Brand- und Explosionsrisiko sowie die Gesundheit am Arbeitsplatz berücksichtigt werden.

Bei der Reinigung von Geräten müssen die Risiken beachtet werden, die beim Zugriff auf gefährliche bewegliche Teile und scharfe Kanten bestehen.

Die sofortige Beseitigung kann erforderlich sein, um die Hygiene zu wahren und mikrobielle Risiken abzuwenden.

#### Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

#### Anlass für die Umsetzung

Senkung des Energie- und Wasserverbrauchs, des Bedarfs an Abwasserbehandlung, des Verbrauchs von Reinigungsmitteln und der Kosten.

#### Beispielanlagen

In vielen Anlagen erfolgt vor der Nassreinigung eine Trockenreinigung.

#### Referenzliteratur

[1, CIAA, 2002, 13, Environment Agency of England and Wales, 2000, 31, VITO, et al., 2001, 41, Nordic Council of Ministers, 2001, 134, AWARENET, 2002]

### **4.3.1.1 Bereitstellung und Verwendung von Filtereinsätzen an Bodenabläufen**

#### Beschreibung

Ein Filtereinsatz ist ein feinmaschiger Siebkorb, der über Bodenabläufen angebracht wird, um das Einwaschen von Feststoffen in das Abwassersystem und die Kläranlage zu verhindern. Filtereinsätze können in ihrer Position verriegelt werden, um sicherzustellen, dass beim Reinigen keine Feststoffe in die Kläranlage gelangen. Wenn sie nach der Trockenreinigung geleert und vor der Nassreinigung wieder in ihrer Position verriegelt werden, kann das Einschleppen löslichen Materials und von durch das Reinigungswasser abgebrochenen Feststoffstücken vermieden werden.

#### Erreichbare Umweltvorteile

Feststoffe, die nicht durch andere Maßnahmen vom Fußboden ferngehalten wurden, gelangen nicht ins Abwasser. So werden die Gehalte an suspendierten Feststoffen, Gesamtstickstoff, Gesamtphosphor, FOG und der BSB und CSB im Abwasser verringert. Die in den Filtereinsätzen aufgefangenen Feststoffe können für geeignete Verwendungen außerhalb der Nahrungsmittelproduktion oder zur Entsorgung abgegeben werden.

#### Medienübergreifende Effekte

Mehr fester Abfall.

#### Betriebsdaten

Die Maschenweite kann je nach Anwendung unterschiedlich sein. Auch die Häufigkeit der Leerungen kann je nach Eigenschaften des potenziell verschütteten Materials unterschiedlich ausfallen.

In Fleischverarbeitungsanlagen kann durch die Verwendung von Filtereinsätzen in Kombination mit Trockenreinigung die Einschleppung von Fleischresten in das Abwasser minimiert werden, ebenso die Eintragung von FOG, die durch den Kontakt zwischen Reinigungswasser und Fleisch- und Fettresten verursacht wird.

### Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

### Wirtschaftliche Aspekte

Sehr billig im Betrieb.

### Anlass für die Umsetzung

Weniger Abwasserkontamination und dadurch einfachere Abwasserbehandlung.

### Beispielanlagen

In der Nahrungsmittelproduktion weit verbreitet.

### Referenzliteratur

[134, AWARENET, 2002, 200, CIAA, 2003]

## **4.3.2 Einweichen von Böden und offenen Geräten, um Schmutz vor der Reinigung zu lösen**

### Beschreibung

Böden und offene Geräte können vor der Nassreinigung eingeweicht werden. Dadurch kann Schmutz gelöst und so die nachfolgende Reinigung erleichtert werden. Weiterhin wird z. B. weniger Wasser mit hohem Druck bzw. hoher Temperatur zum Lösen verhärteten oder eingebrannten Schmutzes benötigt, und die Verwendung chemischer Reinigungsmittel wie Natronlauge kann minimiert werden.

### Erreichbare Umweltvorteile

Je nach Umständen können der Wasserverbrauch und der Energieverbrauch zur Wassererwärmung verringert werden. Auch der Chemikalienverbrauch kann zurückgehen.

### Anwendbarkeit

Anwendbar, wenn verhärteter oder eingebrannter Schmutz bei der Reinigung entfernt werden muss.

### Referenzliteratur

[1, CIAA, 2002]

## **4.3.3 Molchsysteme**

### Beschreibung

Molchsysteme können zur Rückgewinnung wertvoller Produkte aus Rohrleitungen und zur Senkung von Wasser- und Abwasserkosten eingesetzt werden.

Das System besteht aus Molcheinsetz- und -entnahmestationen, Druckluftgeräten und Ventilen in der Leitung, die dem Molch die Bewegung durch das System ermöglichen. Einteilige Molche aus nahrungsmittelgeeignetem Gummi werden mittels Druckluft von einer Einsetzstation aus vorangetrieben und am anderen Ende der Leitung von einem Balken aufgehalten, den zwar das Produkt, nicht jedoch der Molch passieren kann. Der Molch wird mittels eines Ventils, das die Druckluftichtung ändert, zur Einsetzstation zurückgeführt. Durch Fenster an beiden Enden der Leitung kann der Bediener den Molch sehen. Der Molch wird zwischen allen Chargen eingesetzt. Wenn Farb- oder Geschmacksverschleppungen möglich sind, werden zusätzliche Systemspülungen vorgenommen. Aus hygienischen Gründen erfolgt gelegentlich eine CIP-Reinigung, z. B. mit Natronlauge.

### Erreichbare Umweltvorteile und Wirtschaftliche Aspekte

Geringere Produktverluste bei Chargenwechsel und Reinigung; weniger Wasserverbrauch für die Reinigung und eine geringere und weniger belastete Abwassermenge.

### Betriebsdaten

Ein Beispielhersteller von Marmelade hat ein neues Molchsystem wie oben beschrieben installiert. Installation und Bedienschulung wurden vor Ort mit Hilfe des Lieferanten durchgeführt. Regelmäßige Überprüfungen im unternehmenseigenen Labor ergaben, dass das neue System weder den Hygienestandard noch die Produktqualität beeinträchtigt.

Das Beispielunternehmen stellt normalerweise Marmelade für den Großmengenvertrieb in Chargen zu 2,5 Tonnen her. Die gekochte Marmelade wird in zwei Kesseln mit hoher Temperatur zwischengelagert, bevor sie in die Zwischenlagertanks neben dem Verladebereich gepumpt wird, wo die Charge warmgehalten werden kann. Anschließend wird sie in einen Großmengentankwagen gepumpt oder für die Abfüllung in mittelgroße Behälter abgekühlt.

Zusätzlich zu hygienebedingten Reinigungen werden die Leitungen und Gefäße beim Chargenwechsel gereinigt, wenn ein Farbwechsel erfolgt. Für den Großmengenproduktionsprozess bestand die Reinigungsabfolge aus einer Wasserspülung des gesamten Systems, einer CIP-Reinigung der Gefäße, manchmal mit Natronlauge, und einer abschließenden Wasserspülung des gesamten Systems.

Vor der Einführung des Molchsystems erforderte die Gesamtsystemspülung das Ansaugen von Reinigungswasser unter Vakuum durch die Leitungen zwischen den Entfleischungs- und Verdampfergefäßen und den Kesseln und anschließend den Einsatz der Marmeladenpumpe, um das Reinigungswasser durch die Leitungen zur Tankwagenbucht zu pumpen. Da die Marmeladenpumpe nicht für das Pumpen von Wasser ausgelegt ist, erforderte jede Spülung relativ viel Zeit. Außerdem wurde eine große Menge Wasser (5,4 m<sup>3</sup>/Reinigung) verwendet, und zwar normalerweise zweimal täglich. In den Leitungen verbliebene Mengen von Produkt verkäuflicher Qualität wurden mit dem Spülwasser in den Abfluss gespült. Das Anlagenabwasser enthielt daher viele Schwebstoffe und hatte einen hohen CSB.

Beim Chargenwechsel ging in der Leitung immer Marmelade verloren. Nach der Installation des Molchsystems war die Marmeladenausbeute pro Charge höher. Die Menge an rückgewonnenem Produkt in verkäuflicher Qualität beträgt rund 173 Tonnen jährlich. Die Leitungswassermenge, die für das Spülen der Hauptleitung verbraucht wurde, sank von 2.020 m<sup>3</sup>/Jahr auf 310 m<sup>3</sup>/Jahr. Das Abwasservolumen aus der Hauptproduktleitung ging um dieselbe Menge zurück.

Der CSB des Anlagenabwassers ging von einem Spitzenwert von 25.000 mg/l auf etwa 5.000 mg/l zurück, sodass die Kosten pro Einheit um mehr als 76 % von 12 EUR/m<sup>3</sup> auf 2,83 EUR/m<sup>3</sup> sanken. Tabelle 4.25 enthält weitere wirtschaftliche Angaben.

Obwohl der Einsatz des Molchsystems der wichtigste Grund für den Rückgang des CSB ist, geht das Beispielunternehmen davon aus, dass auch die Vakuumreinigung von Senkgruben, Gullis und Nahrungsmittelabscheidern erheblich dazu beiträgt. Im ersten Jahr erforderte das Molchsystem praktisch keine Wartung und es wurden keine neuen Molche benötigt. Das Unternehmen erwartet, dass maximal zwei Molche pro Jahr wegen Abnutzungserscheinungen ersetzt werden müssen. Der Energieverbrauch ging um etwa 680 kWh/Jahr zurück, da das Druckluftsystem weniger Energie als die vorherige Pumpennutzung erfordert.

Das Unternehmen hat vor Kurzem drei weitere Molchsysteme in anderen Leitungen installiert, die nicht der Großmengenproduktion dienen. Es werden erhebliche Kosteneinsparungen und ein weiterer Rückgang des CSB im Abwasser erwartet.

Das Reinigen der Leitungen mit dem Molchsystem erfordert etwas weniger Zeit als mit dem früheren Verfahren.

### Anwendbarkeit

Anwendbar, wo viskose Materialien durch Rohrleitungen transportiert werden, z. B. bei der Herstellung süßer und pikanter Konserven und von Molkereiprodukten wie Joghurt.

### Wirtschaftliche Aspekte

Die jährlichen Kosten und Einsparungen durch den Einsatz eines Molchsystems in der Beispiel-Anlage zur Marmeladenherstellung sind in Tabelle 4.25 angegeben.

| Element  | Einsparung                 | Jährliche Einsparung (EUR) |            | Jährliche Kosten (EUR) |
|--|----------------------------|----------------------------|------------|------------------------|
| Geringerer Abwasser-CSB und geringeres Abwasservolumen | 76 %                       | 167.000                    |            |                        |
| Rückgewonnenes Produkt                                 | 173 t/Jahr                 | 217.000                    |            |                        |
| Weniger Wasserverbrauch                                | 2.020 m <sup>3</sup> /Jahr | 2.000                      |            |                        |
| Geringerer Energieverbrauch                            |                            | 48                         |            |                        |
| Gullireinigung usw.                                    |                            |                            |            | 6.200                  |
| Ersatzmolche (2/Jahr)                                  |                            |                            |            | 180                    |
| Gesamt   |                            | 386.048                    |            | 6.380                  |
| Nettokosteneinsparung                                  |                            |                            | 379.668    |                        |
| Gesamtinvestitionskosten                               |                            |                            | 30.800     |                        |
| Amortisationszeitraum                                  |                            |                            | 4,2 Wochen |                        |

**Tabelle 4.25: Umweltnutzen und Kostenminderung durch den Einsatz von Molchsystemen**

Anlässe für die Umsetzung

Rückgewinnung wertvollen Produkts und geringere Wasser- und Abwasserbehandlungskosten.

Beispielanlage

Mindestens ein Marmeladenhersteller im Vereinigten Königreich.

Referenzliteratur

[1, CIAA, 2002, 57, Envirowise (UK), 2000]

**4.3.4 Entfernung von Restmaterial aus Rohrleitungen mittels Druckluft vor der Reinigung oder vor Produktwechsel**

Beschreibung

Druckluft von Nahrungsmittelqualität kann als Trockenreinigungstechnik zur Beseitigung von Materialresten aus Rohrleitungen verwendet werden, wenn dabei darauf geachtet wird, dass die Staubkonzentration am Arbeitsplatz nicht steigt. Vorteile der Technik sind unter anderem, dass damit der Zugang zu Geräten an Stellen möglich ist, die Molche (siehe Abschnitt 4.3.3) nicht passieren können, und dass sich das Risiko einer Kontamination durch die Einbringung von Reinigungsgeräten vermeiden lässt.

Erreichbare Umweltvorteile

Geringere Produktverluste bei Chargenwechsel und Reinigung; weniger Wasserverbrauch für die Reinigung und eine geringere und weniger belastete Abwassermenge.

Medienübergreifende Effekte

Zur Erzeugung der Druckluft wird Energie verbraucht.

Betriebsdaten

Zur Minimierung der Restbutter in den Rohrleitungen einer Butterherstellungsanlage kann Druckluft dazu verwendet werden, am Produktionsende und vor der Reinigung einen Block gekühlter Butter durch die Leitungen und Ventile zu schieben. Der Effekt ist ähnlich wie der eines Molchsystems, jedoch ist diese Vorgehensweise auch in Geräteteilen möglich, die für Molche nicht zugänglich sind.

Anwendbarkeit

Anwendbar in Anlagen, in denen Pulver und andere Feststoffe mittels Druckluft transportiert werden, und wenn feste, aber komprimierbare Nahrungsmittel einen Raum ausfüllen und Materialien durch diesen Raum drücken können.

Anlass für die Umsetzung

Minimierung von Produktabfällen.

Beispielanlagen

Molkereien in Deutschland in denen Butter hergestellt wird.

Referenzliteratur

[65, Germany, 2002]

### 4.3.5 Wirtschaftlicher Umgang mit Wasser, Energie und Reinigungsmitteln

Beschreibung

Wenn der Verbrauch von Wasser und Reinigungsmitteln sowie die Reinheitszustände täglich aufgezeichnet werden können, lassen sich Abweichungen vom Normalbetrieb erkennen, und laufende Bemühungen zur Senkung des Verbrauchs von Wasser und Reinigungsmitteln ohne Gefährdung der Hygiene können überwacht und geplant werden. Das gilt für alle Reinigungsvorgänge, also manuelle, z. B. mit Druckluft, oder automatische, z. B. als CIP.

Es können auch Versuche durchgeführt werden, z. B. zum Gebrauch von weniger oder gar keinen Reinigungsmitteln, zum Einsatz von unterschiedlich temperiertem Wasser, oder zu mechanischen Reinigungsmethoden, also zur Nutzung der „Kraft“ des Wasserdrucks und zum Gebrauch von Hilfsmitteln wie Scheuerschwämmen und Bürsten.

Durch Überwachung und Regulierung der Reinigungstemperaturen kann der erforderliche Reinheitsstandard von Geräten und Anlagen ohne übermäßigen Gebrauch von Reinigungsmitteln erreicht werden.

Einen wichtigen Beitrag zur Vermeidung von übermäßigem Wasser- und Reinigungsmittelgebrauch im laufenden Betrieb stellt die Schulung des Personals im Umgang mit Reinigungsmitteln, dem Ansetzen von Lösungen und deren Anwendung dar. So sollten beispielsweise Reinigungslösungen nicht in zu hoher Konzentration angesetzt werden, weder durch manuelles Überdosieren noch durch falsche Einstellung von Dosiersystemen. Bei mangelnder Schulung und Aufsicht kommt es schnell zu Überdosierungen, insbesondere beim manuellen Dosieren.

Erreichbare Umweltvorteile

Potenziell verringerter Verbrauch von Wasser, Reinigungsmittel und zur Wassererwärmung benötigter Energie. Das Einsparpotenzial hängt von den Reinigungsanforderungen in den einzelnen Teilen der Anlage oder der Geräte ab, die gereinigt werden sollen.

Betriebsdaten

Unzureichende Maßnahmen zur Hygienesicherung verursachen Probleme mit der Lebensmittelsicherheit, die zu einer Ablehnung des Produkts oder kürzerer Haltbarkeitsdauer führen können. Verbesserungen von Reinigungstechniken lassen sich beispielsweise erzielen, indem Durchflussbegrenzungen der Wasserversorgung und Regulierung des Wasserdrucks von Hochdruck- auf Mittel- oder Niederdruckwäsche für Reinigungen während der Nacht bzw. des Tages vorgenommen werden. Auch die Häufigkeit von Nassreinigungen kann überprüft werden mit dem Ziel, die Zahl der vollständigen Nassreinigungen so weit wie möglich zu reduzieren. In manchen Anlagen kann die erforderliche Hygiene mit einer vollständigen Nassreinigung pro Tag aufrechterhalten werden.

Bei der Planung von Reinigungshäufigkeit und -dauer sollten Größe und Komplexität der Geräte sowie Art und Ausmaß der Verschmutzung berücksichtigt werden.

Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

Wirtschaftliche Aspekte

Die Technik kann zu geringeren Wasser-, Energie- und Reinigungsmittelkosten führen.

Anlass für die Umsetzung

Geringere Wasser-, Energie- und Reinigungsmittelkosten.

Referenzliteratur

[1, CIAA, 2002, 13, Environment Agency of England and Wales, 2000]

### 4.3.6 Ausstattung von Reinigungsschläuchen mit Handauslösern

#### Beschreibung

Wenn zur Heißwasserbereitstellung ein Warmwasserbereiter verwendet wird, können ohne weitere Umrüstung Absperrvorrichtungen mit Handauslösern an den Reinigungsschläuchen angebracht werden. Wenn ein Dampf-Wasser-Mischventil für die Heißwasserversorgung verwendet wird, müssen Kontrollventile installiert werden, damit Dampf bzw. Wasser nicht in die falsche Leitung gelangen. Automatische Absperrventile sind oft mit vormontierten Düsen erhältlich. Düsen verstärken die Wasserkraft und verringern den Wasserdurchfluss.

#### Erreichbare Umweltvorteile

Geringerer Wasser- und Energieverbrauch.

#### Betriebsdaten

In einer Beispiel-Anlage wurde die Energieersparnis für den Betrieb eines Schlauchs berechnet, der mit einem automatischen Absperrventil und einer Düse ausgestattet worden war, und bei dem die Temperatur des benutzten Wassers 71 °C betrug. Vor der Umrüstung betrug der Durchfluss 76 l/min, danach 57 l/min. Vor der Umrüstung lief der Schlauch 8 Stunden/Tag, danach 4 Stunden/Tag. Bei einem Wasserpreis von 21 USD/m<sup>3</sup> errechnete sich eine jährliche Wasserkostenersparnis von 4.987 USD (Preise von 2000). Die errechnete Energieeinsparung betrug 919 GJ pro Jahr.

#### Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

#### Wirtschaftliche Aspekte

Wenn Düsen ohne automatische Absperrventile installiert werden, betragen die Kosten weniger als 10 USD pro Stück. Automatische, auslösergesteuerte Absperrventile mit Düse kosten ungefähr 90 USD pro Stück. (Preise von 2000). Es wurde eine sofortige Amortisation angegeben.

#### Anlass für die Umsetzung

Verringerter Energie- und Wasserverbrauch.

#### Beispielanlagen

Weit verbreitet.

#### Referenzliteratur

[1, CIAA, 2002, 227, Ockerman H. W. and Hansen C. L., 2000]

### 4.3.7 Druckreinigung

Die Druckreinigung wird zum Reinigen von Böden, Wänden, Gefäßen, Behältern, offenen Geräten und Förderbändern sowie als Spülphase nach der Reinigung und Anwendung von Chemikalien eingesetzt. Je nach Reinigungsbedarf kann kaltes oder heißes Wasser verwendet werden.

#### 4.3.7.1 Versorgung mit druckreguliertem Wasser und über Düsen

##### Beschreibung

Wenn die Zufuhr von Wasser unbedingt erforderlich ist, kann dies über Düsen (siehe Abschnitt 4.1.8.8) erfolgen, die an den Prozessgeräten oder an den zur Reinigung von Geräten und/oder Anlagen benutzten Schläuchen angebracht sind. Für Reinigungsvorgänge können die Schläuche über eine Ringleitung mit Wasser versorgt werden. Düsen an Prozessgeräten werden für jede Reinigungsanwendung individuell geplant und positioniert.

##### Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs. Wenn erwärmtes Wasser verwendet wird, lässt sich auch der Gesamtenergieverbrauch senken.

##### Betriebsdaten

Die Wasserflussrate an den einzelnen Düsen kann von der Betriebsleitung je nach Anwendung festgelegt werden. Auch der Wasserdruck kann für denjenigen Reinigungsvorgang eingestellt werden, der den höchsten

Druck erfordert; für die anderen Reinigungsstationen, in denen Wasser gebraucht wird, können geeignete Druckregulierer installiert werden. Der Wasserverbrauch lässt sich optimieren, indem der Wasserdruck und der Zustand der Wasserdüsen überwacht und konstant gehalten werden.

#### Anwendbarkeit

Je nach Betriebslinien-, allgemeinem Betriebs- und Reinigungsbedarf in allen Anlagen der Lebensmittelproduktion anwendbar.

#### Anlass für die Umsetzung

Verringerung des Wasserverbrauchs.

#### Referenzliteratur

[1, CIAA, 2002]

### **4.3.7.2 Hochdruckreinigung unter Verwendung einer zentralen Ringleitung**

#### Beschreibung

Bei der Hochdruckreinigung wird Wasser mit einem Druck zwischen 15 bar, was als Niederdruck gilt, und 150 bar, was als Hochdruck gilt, auf die zu reinigende Oberfläche gespritzt. Auch bei Drücken zwischen etwa 40 und 65 bar wird von Hochdruck gesprochen.

Mobile Druckreinigungsgeräte erfordern längere Stillstandszeiten als solche, die von einer Ringleitung aus versorgt werden. Dieselbetriebene Druckreiniger geben Abgase ab, weshalb sie für Anlagen der Nahrungsmittelproduktion nicht geeignet sind. Elektrisch betriebene Druckreiniger erfordern zusätzliche Bediener-sicherheitsmaßnahmen, darunter Fehlerstromschutzschaltungen, sowie umfangreiche Wartungsarbeiten. Außerdem verbrauchen mobile Geräte den Angaben zufolge mehr Wasser.

Reinigungsmittel werden bei mäßigen Temperaturen von bis zu 60 °C in das Wasser eingebracht. Ein wichtiger Teil der Reinigungswirkung ist mechanischer Natur. Im Vergleich zu Leitungswasserschläuchen werden bei der Druckreinigung weniger Wasser und Reinigungsmittel verbraucht. Es ist jedoch wichtig, einen sicheren und effizienten Druck zu verwenden. In der Nahrungsmittelproduktion bestehen Bedenken hinsichtlich der Hygieneauswirkungen von übermäßigem Spritzen und Aerosolen, die mit dem Einsatz von Hochdruckschläuchen verbunden sind.

Hoch- und Mitteldruckreiniger haben im Vergleich zu Niederdruckreinigern die folgenden Vorteile: geringerer Wasserverbrauch aufgrund der mechanischen Reinigungswirkung des Wasserstrahls; geringerer Chemikalienverbrauch, weil schwere Verschmutzungen durch den Wasserstrahl entfernt werden, und weniger Lebensraum für Bakterien, weil das Wasservolumen geringer ist. Es kann jedoch Bedenken wegen der größeren Aerosolrisiken bei höherem Wasserdruck geben.

Forschungsarbeiten haben ergeben, dass selbst Niederdrucksysteme oberhalb von 1 m zu erheblicher Aerosolbildung führen können und daher während der Produktionszeiten nicht in hygieneempfindlichen Bereichen eingesetzt werden sollten. Es können Trockenreinigungssysteme eingesetzt werden, die für den Gebrauch während der Produktionszeiten vorgesehen sind, und die nicht nur den Wasserverbrauch senken und die Abfallentsorgung optimieren, sondern auch das Risiko von Betriebsstörungen durch Ausrutschen verringern. Außerhalb von Produktionszeiten können sowohl Hoch- als auch Niederdrucksysteme sicher eingesetzt werden. Aufgrund ihrer größeren Effizienz sind Hochdrucksysteme jedoch kostengünstiger. Angaben zufolge ist die Hochdruckreinigung schnell, einfach anzuwenden, effizient und kosteneffektiv.

#### Erreichbare Umweltvorteile

Weniger Wasser- und Chemikalienverbrauch im Vergleich zu herkömmlichen Schläuchen und zur Reinigung mit geringem Druck und hohem Volumen.

#### Betriebsdaten

Ringleitungen haben den Vorteil, dass sie immer einsatzbereit sind. Beim Einsatz von Hochdruckreinigern ist es wichtig, für jede einzelne Anwendung das richtige Gleichgewicht zwischen Druck, Wasservolumen am Einsatzort, Wassertemperatur und Chemikaliendosierung zu erreichen. Bei zu geringem Druck kann die Reinigungsleistung mangelhaft sein, und bei zu hohem Druck steigen das Beschädigungsrisiko für Oberflächen und Geräte und das Verletzungsrisiko für das Personal an.

### Anwendbarkeit

Breiter Anwendungsbereich der Nahrungsmittelproduktion.

### Wirtschaftliche Aspekte

Die Kosteneinsparungen für Dampf, Wasser und Abwasser liegen Angabenzufolge bei Hochdruck-/Niedervolumensystemen gegenüber Niederdruck-/Hochvolumensystemen bei etwa 85 %. Geringere Kosten durch geringeren Chemikalienverbrauch.

### Beispielanlagen

Weit verbreitet.

### Referenzliteratur

[17, Envirowise (UK) and March Consulting Group (UK), 1998]

### **4.3.7.3 Niederdruck-Schaumreinigung**

#### Beschreibung

Die Niederdruckreinigung mit Schaum kann an Stelle der herkömmlichen manuellen Reinigung mit Wasserschläuchen, Bürsten und manuell dosierten Reinigungsmitteln verwendet werden. Sie ist für die Reinigung von Wänden, Böden und Geräteoberflächen geeignet. Ein Schaumreiniger, wie z. B. eine basische Lösung, wird auf die zu reinigende Oberfläche aufgesprüht. Der Schaum haftet an der Oberfläche. Er wird für eine Einwirkzeit von 10 bis 20 Minuten dort belassen und dann mit Wasser abgespült.

Für die Niederdruckreinigung mit Schaum können entweder eine zentrale Ringleitung oder dezentrale Einzelleitungen verwendet werden. Zentrale Systeme können vorgemischte Reinigungslösungen und unter Druck stehendes Wasser von einer Zentraleinheit bereitstellen. Während des Reinigens wechseln sie automatisch zwischen Schaumanwendung und Spülen. Mobile Druckreinigungsgeräte erfordern längere Stillstandszeiten als solche, die von einer Ringleitung aus versorgt werden. Dieselbetriebene Druckreiniger geben Abgase ab, weshalb sie für Anlagen der Nahrungsmittelproduktion nicht geeignet sind. Elektrisch betriebene Druckreiniger erfordern zusätzliche Bediensicherheitsmaßnahmen, darunter Fehlerstromschutzschaltungen, sowie umfangreiche Wartungsarbeiten. Außerdem verbrauchen mobile Geräte den Angaben zufolge mehr Wasser.

#### Erreichbare Umweltvorteile

Weniger Wasser-, Chemikalien- und Energieverbrauch im Vergleich zum Einsatz herkömmlicher Wasserschläuche, Bürsten und manuell dosierter Reinigungsmittel.

#### Betriebsdaten

Eine neue Molkerei in Dänemark, die jährlich 25.000 Tonnen Käse herstellt, verfügt über ein zentrales System mit etwa 50 Satelliteneinheiten, die sich in den verschiedenen Prozessbereichen befinden. Berechnungen zufolge beträgt der Wasserverbrauch 40 % des entsprechenden Verbrauchs bei der herkömmlichen manuellen Reinigung. Das Schaumreinigungssystem funktioniert den Angaben zufolge mit kaltem Wasser von 10 °C, wogegen bei der manuellen Reinigung mit Wasserschläuchen mindestens eine Wassertemperatur von 40 °C erforderlich ist. Die errechneten Einsparungen in diesem Fall betragen 19.800 m<sup>3</sup> Wasser/Jahr und 1.160 MWh/Jahr.

Angabenzufolge zählt zu den Vorteilen der Schaumverwendung die längere Berührungszeit mit verunreinigten Oberflächen, wodurch sich auch bei Verwendung weniger aggressiver Chemikalien bessere Reinigungsergebnisse erzielen lassen. Die chemischen Bestandteile weichen Verschmutzungen auf, wodurch es zu einer besseren Spüeffizienz und Reinigung kommt. Es ist leicht erkennbar, wo Schäume angewendet wurden, und sie sind leicht abzuspülen, so dass weniger Wasser gebraucht wird. Auch die Arbeitskosten sinken, weil die Reinigung im Vergleich zu herkömmlichen Methoden weniger Zeit erfordert. Da weniger aggressive Chemikalien verwendet werden, sinkt auch die Abnutzung von Geräten und das Risiko für den Bediener.

Ein potenzieller Nachteil der Verwendung von Schäumen besteht darin, dass sie aufgrund ihres großen Volumens durch ihr Eigengewicht von Oberflächen abreißen können und so die Einwirkzeit verkürzt wird.

Anwendbarkeit

Anwendbar in neuen und bestehenden Anlagen, zur Reinigung von Böden, Wänden, Gefäßen, Behältern, offenen Geräten und Förderbändern.

Wirtschaftliche Aspekte

Die Investitionskosten für das Schaumreinigungssystem in einer Beispiel-Käseanlage in Dänemark (Angaben von 2000) betragen ungefähr 188.000 EUR bei einer Amortisationszeit von 3,2 Jahren.

Anlass für die Umsetzung

Bessere Reinigung und Beseitigung von Problemen, die mit der Hochdruckreinigung verbunden sind, z. B. die Ausbreitung von Aerosolen, die Schmutzpartikel und Bakterien enthalten.

Beispielanlage

Mindestens eine Käseanlage in Dänemark.

Referenzliteratur

[17, Envirowise (UK) and March Consulting Group (UK), 1998, 42, Nordic Council of Ministers, et al., 2001]

**4.3.7.4 Gelreinigung**Beschreibung

Gele werden üblicherweise für die Reinigung von Wänden, Decken, Böden, Geräten und Behältern eingesetzt. Die Chemikalie wird auf die zu reinigende Oberfläche aufgesprüht.

Erreichbare Umweltvorteile

Weniger Wasser-, Chemikalien- und Energieverbrauch im Vergleich zum Einsatz herkömmlicher Wasser-schläuche, Bürsten und manuell dosierter Reinigungsmittel.

Betriebsdaten

Gelreinigung bietet aufgrund der haftenden Eigenschaften von Gelen auf Oberflächen einen längeren Kontakt zwischen der Verschmutzung und dem aktiven Reinigungsmittel als Schaumreinigung, und Risse werden besser erreicht, da keine störenden Luftbläschen vorhanden sind. Gele sind jedoch transparent und schlecht sichtbar, und können bei hohen Temperaturen unbeständig sein.

Angaben zufolge zählt zu den Vorteilen der Gelverwendung die längere Berührungszeit mit verunreinigten Oberflächen, wodurch sich auch bei Verwendung weniger aggressiver Chemikalien bessere Reinigungsergebnisse erzielen lassen. Die chemischen Bestandteile weichen Verschmutzungen auf, wodurch es zu einer besseren Spüeffizienz und Reinigung kommt. Da Gele sehr leicht abspülbar sind, wird weniger Wasser verbraucht. Auch die Arbeitskosten sinken, weil die Reinigung im Vergleich zu herkömmlichen Methoden weniger Zeit erfordert. Da weniger aggressive Chemikalien verwendet werden, sinkt auch die Abnutzung von Geräten und das Risiko für den Bediener.

Anwendbarkeit

Anwendbar in neuen und bestehenden Anlagen, zur Reinigung von Böden, Wänden, Gefäßen, Behältern, offenen Geräten und Förderbändern.

Anlass für die Umsetzung

Beseitigung von Problemen, die mit der Hochdruckreinigung verbunden sind, z. B. die Ausbreitung von Aerosolen, die Schmutzpartikel und Bakterien enthalten.

Referenzliteratur

[17, Envirowise (UK) and March Consulting Group (UK), 1998]

**4.3.8 Auswahl der Reinigungsmittel**

Die Auswahl der Reinigungsmittel unterliegt mehreren Kriterien, zu denen der Aufbau der Anlage, die zur Verfügung stehenden Reinigungstechniken, die Art der Verunreinigung und die Art des Produktionsprozesses zählen. Reinigungsmittel müssen für ihre Verwendung geeignet sein, aber auch andere Aspekte sind zu beachten. So ist z. B. Glukonsäure weniger ätzend als andere Säuren. Außerdem geht es bei der Reinigung im

Nahrungsmittelbereich nicht nur um die Beseitigung von Verunreinigungen; die Desinfektion ist genau so wichtig.

Auswahl und Anwendung von Reinigungs- und Desinfektionsmitteln müssen eine effektive Hygiene sicherstellen, wobei jedoch die Umweltauswirkungen angemessen zu berücksichtigen sind [1, CIAA, 2002]. Wenn der Einsatz von Reinigungsmitteln unerlässlich ist, muss zuerst überprüft werden, ob mit ihnen ein ausreichendes Maß an Hygiene zu erzielen ist. Anschließend sind ihre potenziellen Umweltauswirkungen zu ermitteln.

Typische in der Nahrungsmittelproduktion verwendete Reinigungsmittel sind:

- Alkalien, z. B. Natrium- und Kaliumhydroxid, Metasilikat, Natriumkarbonat
- Säuren, z. B. Salpetersäure, Phosphorsäure, Zitronensäure, Glukonsäure
- Fertigreinigungsmittel, die Chelatbildner wie EDTA, NTA, Phosphate, Polyphosphate, Phosphonate oder oberflächenaktive Wirkstoffe enthalten
- Oxidierende und nichtoxidierende Biozide.

### 4.3.8.1 Auswahl von Desinfektions- und Sterilisationsmitteln

Die für die Desinfektion und Sterilisation von Geräten und Anlagen verwendeten Chemikalien wirken alle nach dem Prinzip, dass sie die Zellstruktur innerhalb von Bakterien angreifen und deren Vermehrung verhindern. Im Bereich der Nahrungsmittelproduktion eingesetzte Desinfektionsmittel fallen in den Geltungsbereich der Richtlinie 98/8/EG [226, EC, 1998]. Die Bewertung der Auswirkungen von Wirkstoffen in Desinfektionsmitteln auf die Umwelt und die menschliche Gesundheit soll 2007 beginnen [199, Finland, 2003].

Es können verschiedene Behandlungsarten durchgeführt werden. Dazu gehören der Gebrauch oxidierender Biozide, nichtoxidierender Biozide, von UV-Bestrahlung oder Dampf. Informationen zu den Techniken, die oxidierende Biozide, UV-Bestrahlung oder Dampf verwenden, finden sich in den Abschnitten 4.5.4.8, 4.5.4.8.1 und 4.5.4.8.2.

Zu den eingesetzten nichtoxidierenden Bioziden gehören z. B. quartäre Ammoniumsalze, Formaldehyd und Glutaraldehyd. Sie werden allgemein in einer als „Vernebelung“ bezeichneten Technik eingesetzt, bei der die Substanz als feiner Nebel in den zu sterilisierenden Bereich gesprüht wird und die exponierten Oberflächen benetzt. Die Behandlung wird zwischen den Prozessschichten durchgeführt, sodass sich der Nebel verzogen hat, bevor Bediener den Arbeitsbereich betreten. Bei Kontakt mit den Substanzen kann es zu Atemproblemen kommen. Bei der Auswahl und Verwendung von Desinfektions- und Sterilisationsmitteln ist also auch der Gesundheitsschutz am Arbeitsplatz zu berücksichtigen.

### 4.3.8.2 Verwendung von Chelatbildnern

Im Nahrungsmittelproduktionssektor werden Chelatbildner hauptsächlich im Molkereisektor eingesetzt. Saure, basische und oberflächenaktive Reinigungsmittel sowie industrielle Fertigreinigungsmittel enthalten im Allgemeinen Chelatbildner. Diese können Metallionen durch Komplexbildung lösen und inaktivieren. Sie werden zur Beseitigung von Kesselsteinablagerungen und zur Vermeidung von Calcium- und Magnesiumablagerungen eingesetzt, sodass Sedimentierung und Inkrustierung in Rohren, Geräten und Behältern verhindert wird.

Eine der wichtigsten Anwendungen von alkalischen Reinigungsmitteln findet sich im Molkereisektor. Sie finden in verschiedenen Verfahren Anwendung, z. B. in der CIP-Reinigung, bei der Flaschen- und Kistenreinigung, bei der Schaum- und Gelreinigung, bei der Reinigung von Membranen und bei der manuellen Reinigung. Die in der CIP verwendeten Chemikalien sind normalerweise eine alkalische Lösung auf Natronlaugebasis, mit der Fett- und Eiweißschichten gelöst und entfernt werden, und eine saure Lösung, z. B. auf HNO<sub>3</sub>-Basis, zum Lösen und Entfernen von Mineralschichten.

In vielen Fällen ist die Verwendung von Säure bei der CIP nicht erforderlich, und die Reinigung erfolgt nur mit Lauge, sodass es sich um eine Einphasenreinigung handelt. In diesen Fällen können ggf. vorhandene Kalzifizierungen und Ablagerungen den Angaben zufolge nur mithilfe von Chelatbildnern wie EDTA entfernt werden. Das EDTA löst das Calcium aus dem Niederschlag und bricht die Struktur der Ablagerungen auf. Die verbleibenden organischen Substanzen wie Fett- und Eiweißschichten können dann von der alkalischen Lösung abgebaut werden, die üblicherweise auf Natronlauge basiert.

Die am häufigsten verwendeten Chelatbildner sind:

- Ethylendiamintetraessigsäure (EDTA)
- Nitrioltriessigsäure (NTA)
- Methylglycindiacetat (MGDA)
- Phosphate (z. B. Natriumtriphosphat)
- Phosphonate (z. B. DTPMP, ATMP)
- Polyphosphate
- Iminodisuccinat (IDS)
- Enzymatische Detergenzien.

#### 4.3.8.2.1 Verwendung von EDTA

EDTA ist der Chelatbildner, der in den größten Mengen eingesetzt wird. In Westeuropa entfiel 1999 etwa ein Drittel der insgesamt verbrauchten Menge, 10.685 Tonnen, auf industrielle Reinigungsmittel. Für 1997 wurde angegeben, dass deutsche Molkereien jährlich 36 Tonnen EDTA ins Wasser abgaben, also 1 % der Gesamtmenge des Landes.

EDTA wird hauptsächlich wegen seiner Eigenschaft als Chelatbildner für Calcium verwendet. Im Molkereisektor hängt der Calciumgehalt der Milch mit deren Eiweißgehalt in Form von Calciumphosphocaseinat zusammen. EDTA kann in Molkereien während der CIP wie folgt eingesetzt werden:

- Zum Entfernen der als Milchstein bezeichneten Verunreinigungen, die auf den Edelstahloberflächen von Milchverarbeitungsgeräten bei Temperaturen zwischen 70 und 80 °C auftreten. EDTA wird insbesondere bei UHT-Geräten angewendet, bei Membranen z. B. für Ultrafiltration und Umkehrosmose, und für die Vorreinigung von Verdampfern und Sprühtrocknern. Diese Verunreinigungen bestehen hauptsächlich aus stabilen denaturierten Proteinen. Sie werden mit EDTA destabilisiert, wodurch sich die Oberfläche dann reinigen lässt. Kesselstein lagert sich auch in anderen Anwendungen ab, und den Angaben zufolge können erfahrene Bediener feststellen, wann eine regelmäßige Reinigung zur Verhinderung dieser Ablagerungen erforderlich ist. Die Ablagerungen bestehen aus Proteinen, Mineralstoffen und Fett.
- Als härtender Stabilisator zur Vermeidung des Niederschlags von Calcium, wenn konzentrierte alkalische Detergenzien mit Wasser verdünnt werden. Bei der basischen Reinigung mit hohen Temperaturen kann eine Karbonatschicht zurückbleiben, auf der dann ein Biofilm entstehen könnte. Bei der mehrphasigen Reinigung folgt auf die basische Reinigung nach einer Zwischenspülung eine Reinigung mit Salpetersäure. Die Säurereinigung hinterlässt eine glänzende Oberfläche, die mit dem Produkt in Berührung kommt. Bei der Einphasenreinigung wird EDTA zum Abfangen der im Wasser enthaltenen Calciumionen verwendet, sodass dieser Effekt gemindert und der Säureschritt vermieden wird.
- Zum Binden von Calcium, Magnesium und Schwermetallen, um Sedimentierung und Inkrustierung z. B. in den zu reinigenden Leitungen und Gefäßen zu verhindern.
- Die bakterizide Wirkung von Reinigungs- und Desinfektionsmitteln, insbesondere gegenüber gramnegativen Bakterien, wird durch die Einmischung von EDTA verstärkt, da es die äußere Zellwand dieser oft resistenten Arten zerstören kann.
- Zur Verbesserung der Wiederverwendung von Chemikalien und zur Reduzierung des Wasser- und Energieverbrauchs bei der Einphasenreinigung im Vergleich zur Zweiphasenreinigung mit Natronlauge und Salpetersäure.

#### 4.3.8.2.2 Bekannte Risiken im Zusammenhang mit der Verwendung von EDTA

Für andere Chelatbildner liegen keine EU-15-Risikobewertungen vor, sodass nur die Risiken im Zusammenhang mit EDTA im Einzelnen bekannt sind. EDTA bildet sehr stabile und wasserlösliche Komplexe, die in biologischen Kläranlagen normalerweise nicht abgebaut werden. Das bedeutet, dass Schwermetalle nicht in den Klärschlamm übergehen, sondern im Abwasser bleiben und in Oberflächengewässern eingeleitet werden. Das EDTA kann auch Schwermetalle aus dem Sediment in Fließgewässern mobilisieren. Außerdem kann der in EDTA enthaltene Stickstoff zur Gewässereutrophierung beitragen. Auch viele andere Chelatbildner enthalten entweder Stickstoff oder Phosphor.

Der biologische Abbau von EDTA erfolgt langsam und nur unter bestimmten Bedingungen, z. B.:

- lange hydraulische Verweildauer und hohes Schlammalter
- konstante leicht basische Bedingungen
- relativ hohe EDTA-Konzentration
- EDTA darf nicht als Schwermetallkomplex vorliegen.

[125, Boehm, et al., 2002, 126, Knepper and et al., 2001]

Außerdem verursacht EDTA laut Risikobewertungsentwurf vom 7. Februar 2003 gemäß Verordnung 793/93/EWG [201, EC, 1993] ein Risiko für die aquatische Umwelt, wenn es als Chelatbildner in einigen Branchen eingesetzt wird. Der berechnete NOEL in Oberflächenwasser beträgt 2,2 mg EDTA/l.

### 4.3.8.2.3 Verzicht auf EDTA

Angaben zufolge wird EDTA nicht für die Reinigung von Geräten und Gefäßen benötigt, in denen sich Rohmilch befunden hat, z. B. Milchtankwagen, während der Annahme und Lagerung von Geräten oder dem Befüllen mit Flüssigmilch, wo es nur wichtig ist, Fettschichten zu beseitigen oder wo getrennte Reinigungsstationen verfügbar sind. EDTA ist auch nicht für die Reinigung von PET- und Glasflaschen erforderlich.

Durch die Optimierung der Milchverarbeitungszeit und die Verwendung von Rohmilch hoher Qualität, deren Proteine hitzestabiler sind, lässt sich die Bildung von Milchstein verringern (siehe Abschnitt 4.3.8.2.4).

Die mehrphasige Reinigung, also die Verwendung von Säuren und Basen, setzt die Proteinablagerungen vor der basischen Reinigung von Erwärmungsgeräten einer sauren Umgebung aus, sodass die basische Reinigung intensiviert wird. Daran schließen sich dann ein Spülgang und die weitere Reinigung mit gering konzentrierter Salpetersäure an.

Zumindest bei Niedertemperaturpasteurisatoren ist ein Umstieg von der Einphasenreinigung mit EDTA auf die Zweiphasenreinigung mit NTA als Ersatz möglich. In mindestens einem Mitgliedstaat wird die Verwendung von NTA bevorzugt, in einem anderen ist sie verboten. Außerdem ist das mit dem Gebrauch von NTA oder anderen Chelatbildnern verbundene Risiko nicht in demselben Umfang untersucht worden wie für EDTA.

Der Ersatz von gebrauchsfertigen Reinigungsmitteln durch reine Chemikalien kann unter Umständen effizient sein, erfordert aber ein optimales Reinigungsschema und einen genauen Plan der Ablaufdynamik, da es sonst wahrscheinlich zu einem Verlust an Reinigungseffizienz sowie zu erheblichen Hygieneproblemen kommt. Außerdem sind Chelatbildner als Lösungsmittel erforderlich, wenn reine Chemikalien verwendet werden. Aus diesem Grund kann ein gebrauchsfertiges Reinigungsmittel, das an die jeweiligen besonderen Reinigungsaufgaben angepasst ist und in dem die Kombination der Einzelkomponenten bei geringen Konzentrationen wirksam ist, zu viel besseren Reinigungsergebnissen führen [228, Verband der Deutschen Milchwirtschaft (German Dairy Association), 1997].

Im Nahrungsmittelsektor wurde bisher kein Weg gefunden, den Gebrauch von EDTA vollständig zu umgehen, wobei es wahrscheinlich möglich ist, es in weniger Arbeitsschritten einzusetzen und/oder seine Gebrauchshäufigkeit zu verringern. Ein Beispiel für eine Strategie zur Minimierung des EDTA-Gebrauchs ist in Abschnitt 4.3.8.2.5 beschrieben.

### 4.3.8.2.4 Verringerung des EDTA-Gebrauchs durch Minimierung der Milchsteinbildung mittels Produktionsplanung

#### Beschreibung

Durch Verwendung von Milch mit hoher Proteinstabilität lässt sich die Milchsteinbildung reduzieren. Die Stabilität von Milcheiweiß wird durch wiederholte Verarbeitung und Pumpen beeinträchtigt. Daher kann eine Produktionsplanung, die ohne wiederholte Verarbeitung auskommt, zur Vermeidung der Milchsteinbildung und damit des EDTA-Gebrauchs beitragen. Die Milchsteinbildung ist auch stärker, wenn sich viele Mikroorganismen in der Milch befinden, und kann folglich mit der Durchsetzung angemessener hygienischer Bedingungen verringert werden. Es gibt noch eine Reihe weiterer Faktoren, die zur Proteininstabilität in Milch führen, wie beispielsweise Enzymaktivität.

Erreichbare Umweltvorteile

Optimale Milchnutzung und geringerer EDTA-Verbrauch.

Betriebsdaten

Durch die Optimierung der Milchverarbeitungszeit und die Verwendung von Rohmilch hoher Qualität, deren Proteine hitzestabiler sind, lässt sich die Bildung von Milchstein verringern. Milchstein senkt die Wärmetauschereffizienz und die Durchflussrate, insbesondere bei Plattenwärmetauschern. Deshalb müssen indirekte Wärmetauscher spätestens 8 bis 9 Stunden nach Inbetriebnahme gereinigt werden. Bei längeren Zeitabständen zwischen den Reinigungen kann es zu einer Anreicherung von Milchstein kommen, der sich schwerer entfernen lässt. Ein Druckdifferenzmesser kann verwendet werden, um den Druckabfall zwischen der Prozessorzufuhr und -abgabe zu messen und so festzustellen, wann eine Reinigung der Geräte erforderlich ist. Schlechte Milchqualität beeinträchtigt die Laufzeit, da in diesem Fall die Hitzestabilität der Proteine verringert ist und sie sich leichter auf Oberflächen absetzen.

Die Hitzestabilität von Milch lässt sich überprüfen, indem die Milch bis zum Siedepunkt erhitzt und dann die Menge des anfallenden Sediments betrachtet wird. Alternativ kann ein einfacher Test durchgeführt werden, für den man Milch mit Ethanol mischt und überprüft, ob es zur Niederschlagsbildung auf Glasflächen kommt. Stabilere Proteine erfordern höhere Ethanolkonzentrationen, um eine Niederschlagsbildung auszulösen.

Die Milchstabilität ist auch maßgeblich dafür, welche Produkte aus der Milch hergestellt werden können. So ist z. B. für Trinkmilch Milch mit stabileren Eiweißen erforderlich als für die Käseherstellung.

Anwendbarkeit

In allen Molkereien anwendbar.

Anlass für die Umsetzung

Optimale Milchnutzung und geringerer EDTA-Verbrauch.

Referenzliteratur

[245, Barale M., 2004]

**4.3.8.2.5 Beispiel einer Strategie zur Minimierung des EDTA-Gebrauchs**

Eine Beispielmolkerei, in der Molke verarbeitet wird, verbrauchte jährlich 60 Tonnen EDTA, bis ein enzymatisches Verfahren eingesetzt wurde. In dieser Anlage werden täglich zwei Millionen Liter Molke verarbeitet, was 700.000 Tonnen/Jahr entspricht, um Molkeproteinkonzentrat, funktionale Molkeproteinkonzentratprodukte und Molkeproteinextrakt herzustellen. Außerdem werden 13.500 Tonnen Laktose, 10.000 Tonnen Molkepermeat, 5.500 Tonnen Molkeproteinextrakt, 2.000 Tonnen saures Molkepulver und 1.500 Tonnen Milchproteinkonzentrat hergestellt.

Das Unternehmen hat sich bemüht, seine EDTA-Emissionen zu verringern. Anfang 1997 wurde dem Reinigungsmittel Natronlauge zugesetzt mit dem Ziel, die EDTA-Freisetzung um 30 % zu verringern. Dieses Vorgehen erwies sich als nicht effizient. Außerdem testete das Unternehmen 1997 NTA als Ersatz. Dadurch ging der EDTA-Gebrauch um 50 % zurück. Dieser Versuch wurde jedoch wegen der schlechten Reinigungsergebnisse aufgegeben, die zu einer Verschlechterung der mikrobiologischen Produktqualität führten.

Über einen Zeitraum von anderthalb Jahren hinweg wurde dann 1998/99 ein enzymbasiertes Verfahren in der Hauptanlage erprobt. Die Zusammensetzung des Reinigungsmittels wurde geändert. Es stellte sich heraus, dass Chlor und EDTA für die Lösung anorganischer Materialien durch IDS ersetzt werden konnten. Das Verfahren war nicht erfolgreich, wahrscheinlich weil die Reinigung, die den Angaben zufolge zu effektiv war, die sekundäre Membranbeschichtung beeinträchtigte, die für die Proteinfiltration erforderlich ist. Auch nach Ersatz der Membranen passierte dies erneut, sodass sich das Unternehmen entschloss, den Versuch aufzugeben.

Ein ähnliches enzymbasiertes Verfahren in Kombination mit dem Einsatz von Phosphonaten als Chelatbildnern wurde 1999 angewandt, nachdem es 1998 in einer Pilotanlage als Alternativverfahren getestet worden war. EDTA wurde überhaupt nicht verwendet. Dadurch kam es zu Problemen bei der Beseitigung von Calciumverbindungen, insbesondere von Calciumphosphat. Diese führten zu bakteriellen Kontaminationen und Leistungseinbußen.

Daher entschied sich das Unternehmen zur Kombination der letztgenannten Technik mit mehrmals monatlich durchgeführten EDTA-Reinigungsschritten und mit der Wiederverwertung der Reinigungslösung beim Reinigen von Membranen der Nanofiltration [127, Strohmaier, 2002].

### 4.3.9 CIP (Cleaning in Place) und ihr optimaler Einsatz

#### Beschreibung

CIP-Systeme sind Reinigungssysteme, die in Geräte eingebaut sind und so kalibriert und eingestellt werden können, dass sie nur die erforderlichen Mengen an Reinigungsmitteln und Wasser bei der richtigen Temperatur (und ggf. dem richtigen Druck) verwenden. Der Einbau eines CIP-Systems kann bereits bei der Geräteplanung berücksichtigt und vom Hersteller vorgenommen werden. Ein CIP-System nachzurüsten ist u. U. möglich, potenziell aber schwieriger und teurer. CIP-Systeme lassen sich optimieren, indem Wasser und Chemikalien intern wiederverwendet werden, durch sorgfältige Einstellung der Betriebsprogramme, sodass sie den tatsächlichen Reinigungsanforderungen des Prozesses entsprechen, sowie durch die Verwendung wasser-effizienter Spritzsysteme und durch das Entfernen von Produkten und groben Verschmutzungen vor der Reinigung. Ordnungsgemäß für die CIP-Reinigung konstruierte Geräte sollten über Reinigungskugeln verfügen, die so angeordnet sind, dass es keine „toten Zonen“ im Reinigungsprozess gibt.

Sekundärwasser z. B. aus Umkehrosioseprozessen und/oder Kondensat kann für die direkte Verwendung in der Vorspülphase der CIP oder nach Aufbereitung für andere Zwecke geeignet sein. Möglichkeiten zur Wiederverwendung von Sekundärwasser in der CIP in Molkereien sind in Tabelle 4.107 angegeben. Die Verwendung von solchem Wasser für das Vorspülen kann davon abhängen, ob es möglich ist, Material für die Wiederverwendung im Prozess rückzugewinnen. Wenn das der Fall ist, muss das Wasser Trinkwasserqualität haben.

Die in der CIP verwendeten Chemikalien sind normalerweise eine alkalische Lösung auf Natronlaugenbasis, mit der Fett- und Eiweißschichten gelöst und entfernt werden, und eine saure Lösung, z. B. auf  $\text{HNO}_3$ -Basis, zum Lösen und Entfernen von Mineralschichten. In vielen Fällen ist der Säureschritt nicht erforderlich. Reinigung nur mit dem basischen Schritt wird manchmal als Einphasenreinigung bezeichnet. Chelatbildner, normalerweise auf EDTA-Basis, werden manchmal zur basischen Lösung zugegeben, sowohl um die Niederschlagsbildung zu vermeiden, die normalerweise beim Verdünnen von basischen Konzentraten auftritt, als auch um Kalzifizierungen und Ablagerungen zu lösen. Chelatbildner und andere Additive können umweltschädlich sein. Die Abschnitte 4.3.8.2 bis einschließlich 4.3.8.2.5 enthalten weitere Angaben zur Verwendung von Chelatbildnern, darunter auch EDTA. Vorteile der Einphasenreinigung sind der geringere Wasser- und Energieverbrauch und die schnellere Reinigung. Wenn sowohl basische als auch saure Reinigungslösungen verwendet werden, sind zwei Reinigungslösungstanks mit zusätzlichen Leitungen und Zwischenspülungen erforderlich, sodass mehr Wasser und Energie verbraucht wird und die Reinigung länger dauert.

Die Wahl der verwendeten Reinigungsmittel hängt von einer Reihe von Faktoren ab und lässt sich nicht allgemeingültig festlegen. Für bestimmte Anwendungen sind einfache basische Materialien wie Natronlauge und  $\text{HNO}_3$  sowie eigens angemischte, gebrauchsfertige Reinigungsmittel erhältlich. Es ist sorgfältig darauf zu achten, dass nicht benötigte Chemikalien auch nicht verwendet werden. Das gilt z. B. für Chelatbildner wie EDTA-haltige Reinigungsmittel, die für die Reinigung von Milchtanklastern und Rohmilchlagertanks nicht erforderlich sind.

Abbildung 4.21 zeigt ein Beispiel für ein CIP-System.

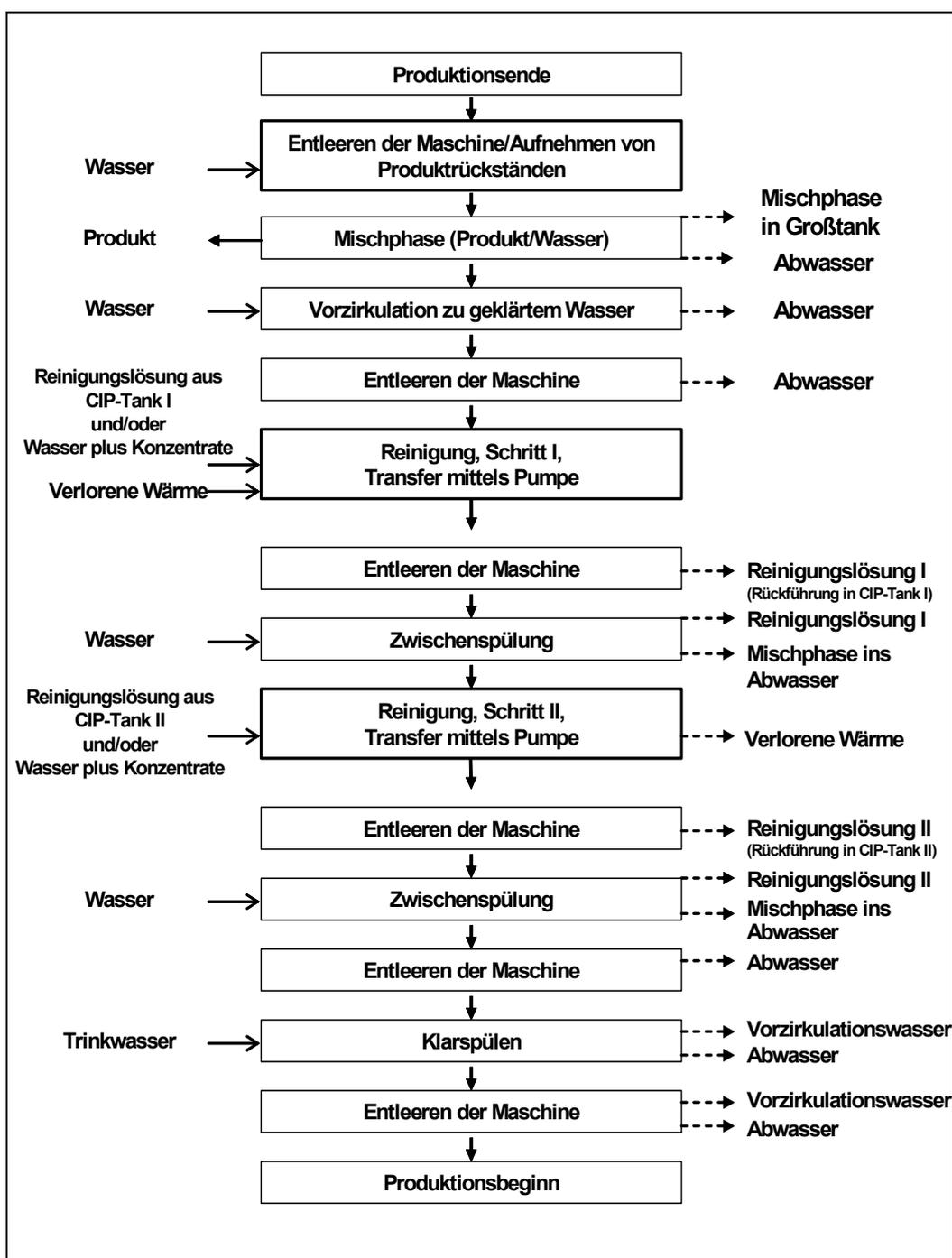


Abbildung 4.21: Flussdiagramm eines Cleaning-in-place-Systems

Den Angaben zufolge sollte die parallele oder serielle Reinigung von Tanks sowie die parallele Reinigung von Leitungssystemen vermieden werden. Sowohl die parallele als auch die serielle Reinigung von Tanks führt zu einer übermäßigen Vermischung von Vorspül- und Reinigungslösung sowie von Reinigungslösung und letzter Spülung. Dadurch wird die Wiederverwendung von Reinigungslösung und Energie eingeschränkt. Bei parallelen Konfigurationen kann es schwierig sein, die erforderliche Verteilung der Ströme durch mehr als einen Tank zu erzielen. Außerdem benötigt die CIP-Rückführung von den Tanks eine andere Verweildauer. Beim Umschalten von der Vorspül- auf die Reinigungslösung oder von der Reinigungslösung auf die letzte Spülung ergibt sich so eine längere Mischzone. Bei seriellen Konfigurationen ergibt sich durch den Inhalt der Leitungen zwischen Tank I und Tank II, wenn er nicht zuerst abgelassen wird, ebenfalls eine lange Mischzone. Wenn die Reinigungslösung in Tank I eintrifft (abgelassen), kommt es möglicherweise zu einer Vermischung des Vorspülungsinhalts der Leitungen mit der Reinigungslösung in Tank II (zuvor abgelassen).

### Erreichbare Umweltvorteile

Der Verbrauch von Wasser, Reinigungsmitteln und Energie für die Erwärmung des Wassers lässt sich verringern, da die Einstellungen so vorgenommen werden können, dass nur die für die zu reinigende Oberfläche erforderliche Menge eingesetzt wird. Wasser und Chemikalien lassen sich innerhalb des Systems rückgewinnen und wiederverwenden. Dadurch ergibt sich auch eine Verringerung der Abwassermenge.

### Medienübergreifende Effekte

Möglicherweise Energieverbrauch durch das Pumpen von Wasser und Reinigungsmitteln.

### Betriebsdaten

Mit der Optimierung des CIP-Systems kann beispielsweise die Menge der verwendeten Reinigungs- und Desinfektionsmittel durch Rückführung der Reinigungslösungen gesenkt werden. Durch kontaminiertes Wasser und Lösungen kommt es dennoch zu Verlusten, die wieder ausgeglichen werden müssen. Wenn beispielsweise der Feststoffgehalt einer Reinigungslösung eine bestimmte Konzentration erreicht, so muss die Lösung entsorgt werden. Ein weiterer Effekt der Rückführung von Lösungen ist, dass deren thermische Energie teilweise rückgewonnen werden kann.

CIP-Systeme können viel effizienter sein als die manuelle Reinigung, aber sie müssen entsprechend geplant und eingesetzt werden, damit ihre potenziellen Vorteile optimiert werden. Zu den Planungs- und Betriebsmerkmalen, die den Verbrauch von Wasser und Reinigungschemikalien minimieren und die Produktrückgewinnung maximieren, zählen folgende:

- Entfernung von trockenem Produkt, bevor der Nassreinigungszyklus einsetzt, z. B. durch einfaches schwerkraftbedingtes Ablaufen, durch Molchsysteme (siehe Abschnitt 4.3.3) oder unter Verwendung von Druckluft (siehe Abschnitt 4.3.4)
- Vorspülen mit geringen Wassermengen, die in manchen Fällen entweder mit dem rückgeführten Vorspülwasser zur Wiederverwendung im Prozess rückgeführt oder für die Entsorgung zurückgewonnen werden können
- Verwendung eines Trübungsdetektors zur Optimierung sowohl der Rückgewinnung von Material/Produkt aus dem Wasser als auch zur Wiederverwendung von Reinigungswasser beim Vorspülen (siehe Abschnitt 4.1.8.5.3)
- Optimierung des CIP-Programms für die Größe der Anlage/des Gefäßes und die Art der Verschmutzung, und zwar hinsichtlich Chemikaliendosierung, Wasserverbrauch, Temperatur, Druck, Reinigungs- und Spülzeiten
- automatische Dosierung von Chemikalien in den richtigen Konzentrationen
- interne Wiederverwertung von Wasser und Chemikalien
- Wiederverwendung von Zwischen-/Endwasser für das Vorspülen
- Steuerung der Wiederverwendung nach der Leitfähigkeit (siehe Abschnitt 4.1.8.5.2), nicht zeitabhängig.
- wassereffiziente Spritzsysteme
- richtige Auswahl der CIP-Reinigungsmittel.

Die Wiederverwendung des Spülwassers aus dem letzten Spülgang ist gängige Praxis, z. B. für das Vorspülen, Zwischenspülen oder Herstellen von Reinigungslösungen. Ziel der letzten Spülung ist es, auch noch die letzten Spuren von Reinigungslösungen aus dem gereinigten Gerät zu entfernen. Dafür wird sauberes Wasser verwendet, und das Spülwasser, das zur zentralen CIP-Einheit rückgeführt wird, ist sauber genug, um wiederverwendet und nicht direkt in das Abwasser geleitet zu werden. Die Rückgewinnung des Wassers aus der letzten Spülung erfordert eine Verbindung von der CIP-Rückführleitung zum Vorspültank. Zur Umleitung des Wassers, z. B. in den Vorspültank, wird ein Leitfähigkeitstransmitter verwendet.

In großen Molkereien mit stark verzweigtem Leitungssystem ist ein zentrales CIP-System unter Umständen nicht geeignet. Oft sind die Entfernungen zu groß, sodass es zu erheblichen Verlusten an Wärme, Reinigungsmitteln und Wasser kommt und außerdem übermäßige Pumpenkapazitäten erforderlich sind. In solchen Fällen können mehrere kleine CIP-Systeme eingesetzt werden. Diese können über eine geschlossene Leitung vom zentralen CIP-System mit den erforderlichen Reinigungslösungen versorgt werden.

Für manche Anwendungen, wie z. B. kleine oder selten genutzte Anlagen oder solche, in denen die Reinigungslösung stark verschmutzt wird, wie beispielsweise in UHT-Anlagen, Membrantrennungsanlagen und bei der Vorreinigung von Verdampfern und Sprühtrocknern, werden Einmalsysteme verwendet. In diesen Systemen

werden Reinigungsmittel nicht wiederverwendet, weil sie den Reinigungseffekt in anderen Anlagen beeinträchtigen könnten.

#### Anwendbarkeit

Anwendbar bei geschlossenen/abgedichteten Geräten, durch die Flüssigkeiten zirkuliert werden können, also z. B. Leitungen und Gefäße.

#### Wirtschaftliche Aspekte

Die Investitionskosten sind hoch. Geringere Kosten für Wasser, Energie und Chemikalien.

#### Anlass für die Umsetzung

Automatisierung und einfache Bedienung. Die Geräte müssen nicht so oft zerlegt und wieder zusammengebaut werden.

#### Beispielanlagen

Die CIP wird in vielen Molkereien, Brauereien und bei der Herstellung von löslichem Kaffee eingesetzt. Außerdem findet sie Verwendung bei der Reinigung von Geräten für die Weinstabilisierung.

#### Referenzliteratur

[1, CIAA, 2002, 9, Verband der Deutschen Milchwirtschaft (German Dairy Association), 1999, 42, Nordic Council of Ministers, et al., 2001, 224, Portugal-FIPA, 2003, 228, Verband der Deutschen Milchwirtschaft (German Dairy Association), 1997, 239, CIAA-EDA, 2003]

### **4.3.10 Häufige und sofortige Reinigung von Prozessgeräten und Materiallagerbereichen**

Siehe auch Abschnitt 4.3.1.

#### Beschreibung

Bereiche, in denen Rohmaterial, Nebenprodukte und Abfall gelagert werden, müssen häufig gereinigt werden. Das Reinigungsprogramm kann sich auf die gesamte Betriebseinheit, Geräte und inneren Oberflächen, Materiallagerbehälter, Drainagen, Höfe und Straßen erstrecken.

#### Erreichbare Umweltvorteile

Wenn gründliche Reinigungen und gute handwerkliche Praxis routinemäßig durchgeführt werden, verringern sich übelriechende Emissionen und das Risiko von Hygiene- und Belästigungsproblemen durch Ungeziefer und Schädlinge.

#### Medienübergreifende Auswirkungen

Beim Reinigungsvorgang wird Wasser verbraucht, wobei die Menge des Verbrauchs jedoch vom Umfang der vor dem Wassereinsatz durchgeführten Trockenreinigung abhängig ist. Es besteht eventuell die Möglichkeit, Wasser aus Quellen innerhalb der Anlage und aus der Kläranlage wiederzuverwenden.

#### Betriebsdaten

Wenn Hackfleischreste, insbesondere Fleischmischungen für die Salami- oder Wurstherstellung in Geräten wie Kuttern und Wurstfüllmaschinen sowie auf Fußböden, nicht entfernt werden, kleben sie an den Oberflächen fest und erschweren die spätere Reinigung. Wenn diese Geräte unmittelbar nach dem Produktionsende gereinigt werden, lassen sich Reinigungsanstrengung, Wasser- und Reinigungsmittelbedarf minimieren. Soweit praktisch möglich, werden die Hackfleischreste vor der Reinigung manuell entfernt und an Anlagen zur Verwertung tierischer Nebenprodukte weitergegeben.

Wenn Rohmaterialbehälter häufig, z. B. täglich, geleert und ausgewaschen werden, reichern sich verrottende und übelriechende Materialien nicht über lange Zeiträume an. Verzögerungen beim Versand können ausreichend Zeit für das Verrotten des Materials bieten, und wenn die Lagerung, insbesondere unter schlecht regulierten Bedingungen, auch nur kurz in der Anlage erfolgt, kann es zu Geruchsproblemen kommen. Selbst Einrichtungen, in denen sauberes Material schnell umgeschlagen wird, können Geruchsprobleme verursachen, wenn keine guten Hygienepraktiken eingehalten werden. So können beispielsweise aussortiertes Obst und Gemüse, Schäl- und Schnittreste sowie organische Abfälle täglich geleert werden.

### Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

### Beispielanlagen

Weit verbreitet, z. B. in der Obst- und Gemüselagerung.

### Referenzliteratur

[41, Nordic Council of Ministers, 2001]

### **4.3.11 Verwendung von Hochdrucksprühreinigern (HPLV-Sprühvorrichtungen) zur Reinigung von Lastwagen**

#### Beschreibung

Durch die Verwendung von Hochdrucksprühreinigern, die mit hohem Druck und geringem Mengendurchsatz (high pressure low volume, HPLV) arbeiten, können für die Reinigung von Lastwagen der Wasserverbrauch und die Abwasserbelastung reduziert werden.

#### Erreichbare Umweltvorteile

Verringerung von Wasserverbrauch und Abwasserkontamination.

#### Betriebsdaten

Weintraubenbehälter werden Angaben zufolge mit dieser Technik gereinigt. Das Reinigungswasser wird abgeleitet.

#### Anwendbarkeit

Anwendbar in Anlagen der Nahrungsmittelproduktion, bei denen Material in Lastwagen angeliefert wird.

#### Wirtschaftliche Aspekte

Geringere Kosten für Wasser und Abwasserbehandlung.

#### Beispielanlagen

Wird in Weinkellereien verwendet.

#### Referenzliteratur

[134, AWARENET, 2002]

## **4.4 Techniken zur Minimierung von Luftemissionen**

Die Arten von Umweltauswirkungen von Arbeitsabläufen in der Nahrungsmittelproduktion werden nach Produktgruppen in Table 3.4 zusammengefasst, und für die betroffenen Emissionen in die Luft sind in Table 3.5 erläutert.

Dieser Abschnitt besteht aus drei Hauptteilen. In Abschnitt 4.4.1 wird ein systematischer Ansatz zur Überwachung von Luftemissionen beschrieben, angefangen bei der Definition des Problems, bis hin zur Auswahl der besten Lösung. In Abschnitt 4.4.2 werden prozessintegrierte Techniken beschrieben, die zur Vermeidung oder Verminderung von Luftemissionen eingesetzt werden. In Abschnitt 4.4.3 schließlich werden nachgeschaltete Techniken beschrieben, die nach den prozessintegrierten Maßnahmen zum Einsatz kommen.

### **4.4.1 Strategie zur Überwachung von Luftemissionen**

Die Strategie gliedert sich in eine Reihe von Bewertungsstufen. In welchem Ausmaß die einzelnen Stufen angewendet werden müssen, hängt von der Situation in der jeweiligen Anlage ab. Auf manche Stufen kann zum Erzielen des gewünschten Schutzes unter Umständen verzichtet werden. Diese Strategie kann für alle Luftemissionen verwendet werden, also für Gase, Stäube und Gerüche, von denen manche durch VOC-Emissionen verursacht werden. Gerüche stellen in erster Linie eine örtlich begrenzte Belästigung dar, aber da sie oft durch VOC-Emissionen verursacht werden, müssen sie auch berücksichtigt werden. Jede Stufe wird anhand des Beispiels Geruch veranschaulicht. Der Ansatz in diesem Beispiel, der in Abbildung 4.22 zusammengefasst ist, eignet sich besonders für große Betriebsstandorte, an denen es viele unterschiedliche Geruchsquellen gibt, ohne dass genau bekannt ist, welche Prozesse/Punkte am stärksten zu den übelriechenden Belästigungen beitragen.

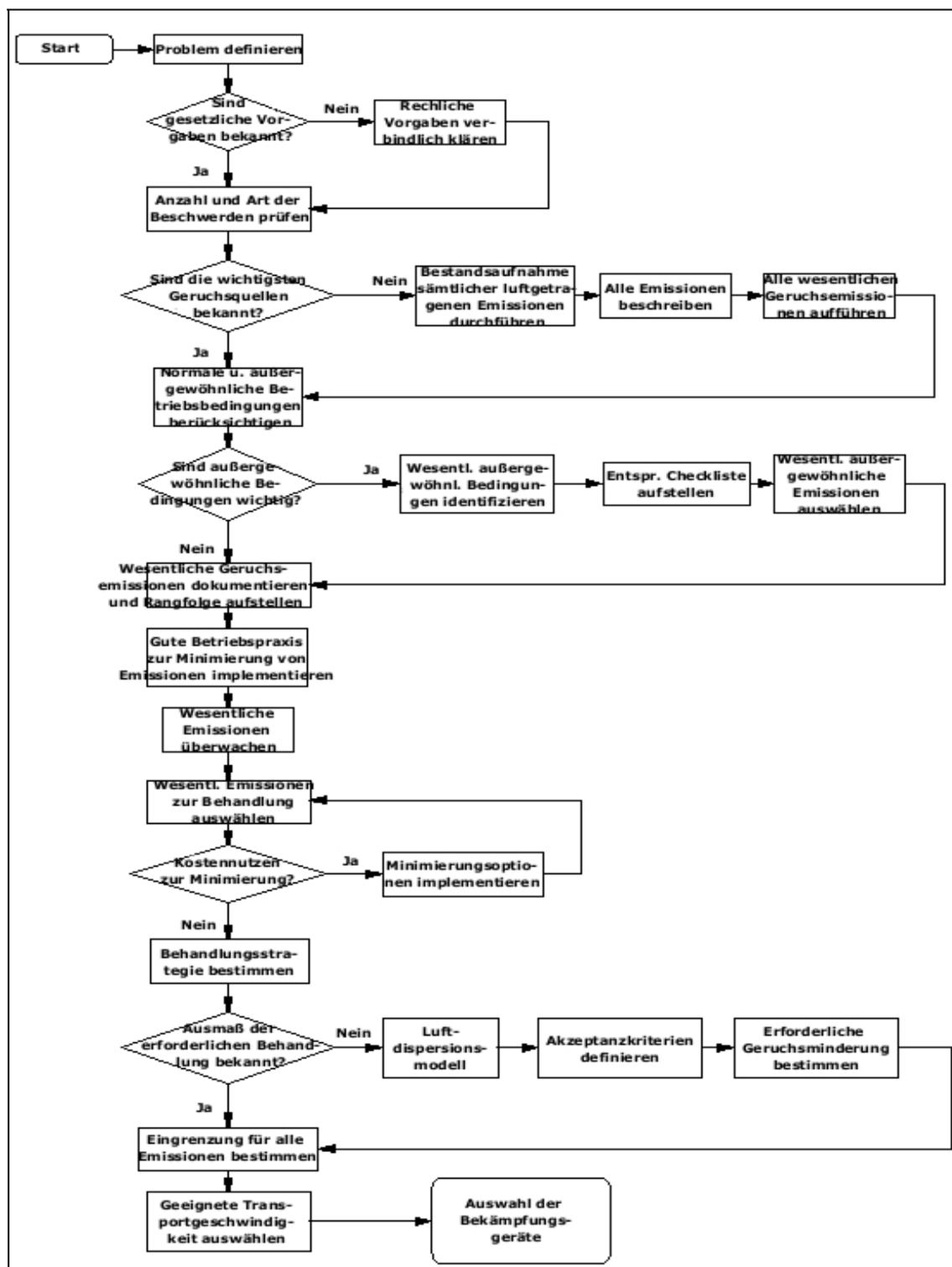


Abbildung 4.22: Flussdiagramm für die Auswahl von Geruchsminderungstechniken [34, Willey A R and Williams D A, 2001]

#### 4.4.1.1 Schritt 1: Definition des Problems

Es werden Informationen zu den gesetzlichen Bestimmungen über Luftemissionen zusammengetragen. Bei der Definition des Problems, z. B. für Gerüche, können auch örtliche Gegebenheiten wie Wetter und geografische Bedingungen eine Rolle spielen.

### 4.4.1.1.1 Beispiel Geruch

Die in der Anlage Beschäftigten wissen im Allgemeinen gut über die Geruchsprobleme Bescheid und können einem Berater oder anderen, mit den örtlichen Gegebenheiten nicht vertrauten Personen helfen.

Zuerst können Anzahl und Häufigkeit der Beschwerden über die Gerüche und deren Eigenschaften überprüft werden. Die Lokalisierung der Beschwerden, bezogen auf die Anlage, und die Bemerkungen der Beschwerdeführer oder von Vertretern örtlicher Behörden können dabei helfen, herauszufinden, was getan werden muss. Es kann ein Protokolliersystem für Beschwerden eingerichtet werden, zu dem auch ein System gehört, mit dem sichergestellt wird, dass auf alle Beschwerden, die direkt bei der Anlage eingehen, telefonisch oder mit einem Besuch reagiert wird. Wenn die genauen Verarbeitungsbedingungen zum Beschwerdezeitpunkt untersucht und dokumentiert werden, so lässt sich das Auffinden der Geruchsquellen, die zu überwachen sind, vereinfachen.

Gegebenenfalls kann die Korrespondenz mit den örtlichen Behörden oder der Gemeinde überprüft werden. Das Aktivitätsniveau in der örtlichen Gemeinde zusammen mit Ansatz und Maßnahmen, die von Vertretern der örtlichen Behörden ergriffen wurden, können zur Feststellung der Wichtigkeit des Problems beitragen und den Teilrahmen für Prozessänderungen und für die Installation von Minderungseinrichtungen beeinflussen.

Schließlich lassen sich die vorwiegenden örtlichen Klimabedingungen feststellen. Insbesondere von Bedeutung sind die Hauptwindrichtung, die normale Windgeschwindigkeit und die Häufigkeit von Inversionen. Diese Informationen können dazu verwendet, um festzustellen, ob die Beschwerden in erster Linie auf bestimmte Wetterbedingungen oder auf bestimmte Arbeitsabläufe in der Anlage zurückzuführen sind.

### 4.4.1.2 Schritt 2: Bestandsaufnahme der Emissionen der Betriebsstätte

In der Liste sind normale und außergewöhnliche betriebliche Emissionen zu erfassen. Durch die genaue Beschreibung eines jeden Emissionspunktes können anschließend ein Vergleich mit anderen Emissionspunkten und eine Rangfolgenbildung für den ganzen Standort erfolgen.

Ein systematischer Weg zur Identifizierung von Luftemissionen bei normalem Betrieb besteht darin, alle Prozesse einzeln durchzugehen und sämtliche potenziellen Emissionen festzustellen. So können in einer solchen Untersuchung beispielsweise die folgenden Arbeitsbereiche abgedeckt werden:

- Anlieferung von Rohmaterial
- Massenlagerung von Rohmaterial
- Lagerung kleinerer Einheiten von Rohmaterial, z. B. in Gebinden und Säcken
- Produktion
- Verpackung
- Palettierung/Lagerung

Diese Untersuchung kann unterschiedlich detailliert ausgearbeitet werden. Bei einer Begehung der Betriebsstätte können Prozessflussdiagramme oder Prozess- und Gerätediagramme verwendet werden, um systematisch sämtliche Emissionsquellen festzustellen.

Je nach Bedeutsamkeit des Problems und den wichtigsten Arbeitsabläufen in der Anlage, die das Problem verursachen, kann es notwendig sein, diese Untersuchung auf außergewöhnliche Situationen und sogar auf Notfallsituationen auszudehnen. Es kann ein Checklistenverfahren in Kombination mit einem Prozess- und Gerätediagramm verwendet werden. Welche Schlagworte in die Checkliste aufgenommen werden sollten, ist wahrscheinlich von Arbeitsgang zu Arbeitsgang stark unterschiedlich.

### 4.4.1.2.1 Beispiel Geruch

Geruchsprobleme können auf eine kontinuierliche Freisetzung von Abluft durch eine Anlage zurückzuführen sein, welche einen charakteristischen Geruch in der Umgebung verbreitet. Wenn die Hauptemission behandelt wird, ist in vielen Fällen das Problem weitgehend behoben und es gehen nur noch wenig oder gar keine Beschwerden mehr ein. In anderen Fällen führt die Beseitigung der Hauptgeruchsquelle dazu, dass andere am Standort vorhandene Geruchsquellen deutlicher wahrnehmbar werden. Diese Geruchsquellen können andere Eigenschaften als die Hauptgeruchsquelle aufweisen. In einer solchen Situation kann es daher zu weiteren Beschwerden kommen, und es können weitere Investitionen über die bereits zur Minderung der Hauptgeruchs-

quelle getätigte hinaus nötig werden. Deshalb ist es wichtig, die gesamte Bandbreite übelriechender Emissionen am Standort zu bewerten und diejenigen Einzelemissionen zu identifizieren, die am ehesten zu Beschwerden über Geruchsprobleme führen können. Tabelle 4.26 zeigt eine Möglichkeit der Aufzeichnung von Angaben zu Geruchsquellen unter normalen Betriebsbedingungen. Es kann auch der Fall sein, dass Geruchsprobleme nur unter außergewöhnlichen Betriebsbedingungen auftreten. Tabelle 4.27 enthält eine typische Checkliste für außergewöhnliche Betriebsituationen.

| Geruchsquelle: _____          | Beispiele: _____                                      |
|-------------------------------|---|
| Art der Freisetzung           | Mit Druck/natürlich/Belüftung                         |
| Durchgeführter Arbeitsschritt | Erwärmung/Kühlung/Wartung/Reinigung                   |
| Kontinuität der Emission      | Kontinuierlich/nicht kontinuierlich/periodisch        |
| Betriebszeit                  | Dauer pro Stunde/pro Tag/pro Produktionszyklus        |
| Freisetzungsort               | Schornstein/Einstiegsöffnung/im Gebäude/atmosphärisch |
| Freisetzungskonfiguration     | Schornsteindurchmesser / Ableithöhe                   |
| Geruchsbeschreibung           | Süß/sauer/stechend/fruchtig                           |
| Geruchsstärke                 | Sehr leicht/leicht/deutlich/stark/sehr stark          |
| Geschätzte Flussrate          | Messung/Gebläsekurven/Schätzung                       |
| Lage auf dem Betriebsgelände  | Koordinaten des Ausstoßes                             |
| Betrieb                       | Normal/außergewöhnlich/Notfall                        |
| Rangfolge insgesamt           | z. B. -10 bis +10 oder 0 bis 10                       |

**Tabelle 4.26: Datenblatt für die Erhebung von Angaben zu übelriechenden Emissionen**

| Parameter                                     | Beispiele   |
|---|---|
| Austritt                                      | Überfüllung/Lecks/Fehlerkontrolle                     |
| Entsorgungsentleerung                         | Abfallmaterial und Prozessmaterial                    |
| Potenzial für Materialeintritt in den Prozess | Bruch der Dampfspirale                                |
| unkontrollierte Reaktion                      | Materialstörung oder Versagen der Temperaturkontrolle |
| Korrosion/Erosion                             | Inspektionshäufigkeit                                 |
| Ausfall von Diensten                          | Ausfallsichere Geräte                                 |
| Steuerung/Personalbesetzung                   | Grad an Steuerung und Überwachung                     |
| Belüftung/Abzug                               | Korrekte Planungsbasis                                |
| Wartung/Inspektion                            | Häufigkeit, was ist erforderlich?                     |
| Hochfahren/Herunterfahren                     | Auswirkungen auf nachgelagerte Arbeitsschritte        |
| Änderungen im Durchsatz                       | 100 %, 110 % der Produktion und geringe Produktion    |
| Änderungen der Zusammensetzung                | Übelriechende Bestandteile                            |

**Tabelle 4.27: Checkliste für außergewöhnlichen Betrieb**

Die übelriechenden Emissionen können nach Bedeutung ihrer Auswirkung auf die Umgebung geordnet werden. Ein mögliches System für eine Rangfolgenbildung könnte damit beginnen, dass die Emissionen Kategorien zugeordnet werden, z. B. stark, mittel und schwach, und zwar gemäß ihren Geruchseigenschaften und den diesbezüglichen Beschwerden. Die Rangfolgenbildung innerhalb der einzelnen Kategorien wird wesentlich von der Stärke des von der Quelle ausgehenden Geruchs in Kombination mit dem damit verbundenen Luftstrom und der jeweiligen Art des Betriebs, also kontinuierlich oder nicht kontinuierlich, bestimmt. Neben den oben angeführten Faktoren kann für diesen Prozess auch eine professionelle Beurteilung erforderlich sein.

#### 4.4.1.3 Schritt 3: Messung wesentlicher Emissionen

Die Luftemissionen werden quantifiziert, damit die Prioritäten hinsichtlich Vorbeugung und Behandlung gesetzt werden können. Die Messungen ermöglichen eine Rangfolgenbildung der Emissionen nach der Größenordnung ihrer Auswirkungen.

4.4.1.3.1 Beispiel Geruch

Die Quantifizierung der wesentlichen übelriechenden Emissionen erfolgt nach der folgenden Formel:

$$\text{Geruchsemission} = \text{gemessene Geruchskonzentration (GE/m}^3\text{)} \times \text{damit verbundener Volumenstrom (m}^3\text{/Sek.)}$$

Geruchsmessungen sind schwierig, und die Ergebnisse weisen unter Umständen breite statistische Abweichungen auf. Trotzdem kann eine quantitative Bestimmung des Geruchs letztlich durch einen Lieferanten, der Minderungstechnik installieren soll, oder zum Nachweis der Einhaltung gesetzlicher Vorgaben erforderlich sein.

Wenn die wichtigsten übelriechenden Emissionen bekannt sind, kann in Verbindung mit den entsprechenden Durchflüssen und dem Ort der Emissionen auf dem Betriebsgelände ein mögliches Behandlungsszenario entwickelt werden. Tabelle 4.28 basiert auf einer realen, aber nicht näher bezeichneten Situation, die zur Veranschaulichung des Prinzips vereinfacht wurde. Sie zeigt die Berechnung von Geruchsemissionen und eine entsprechende „Emissionsrangfolge“. Daraus lässt sich eine vorläufige Behandlungsstrategie entwickeln. Es wird an dieser Stelle jedoch noch nicht überprüft, ob die Betriebsstunden oder die Auswirkungen der Hauptemissionen einschließlich ihrer individuellen Eigenschaften (z. B. starker, süßer oder stechender Geruch) weiter berücksichtigt werden müssen,.

| Quelle                                   | Volumenstrom (m <sup>3</sup> /s) | Geruchskonzentration (GE/m <sup>3</sup> ) | Geruchsemission (GE/s) | Emissionsrang nach der Geruchsemission* | Betriebsstunden (Std./Jahr) | Geruchsbeschreibung |
|--|----------------------------------|---|------------------------|---|-----------------------------|---------------------|
| Handhabung von Rohmaterial               | 180.000                          | 1.610                                     | 22                     | 5                                       | 480                         |                     |
| Erwärmung von Rohmaterial                | 172.800                          | 1.250                                     | 16                     | 6                                       | 960                         |                     |
| Prozess-erwärmung                        | 3.960                            | 11.290                                    | 3,4                    | 7                                       | 2.100                       |                     |
| Vakuum-erzeugung                         | 1.440.000                        | 17.180                                    | 1.909                  | 2                                       | 5.760                       |                     |
| Fett-abscheidung                         | 5.760                            | 90  | 0,04                   | 8                                       | 6.240                       |                     |
| Abluft von der Prozessanlage in die Luft | 6.912.000                        | 350                                       | 190                    | 4                                       | 48                          |                     |
| Verpackungshalle                         | 45.720.000                       | 80  | 275                    | 3                                       | 5.760                       |                     |
| Abfallanlage                             | 12.600.000                       | 2.690                                     | 2.611                  | 1                                       | 387                         |                     |

\* Hierbei werden Geruchsauswirkungen, Expositionszeiten und andere Eigenschaften nicht berücksichtigt. Nummer 1 hat die höchste Behandlungspriorität, da hier die höchste Emissionskonzentration besteht, und die Prioritäten sinken dann bis auf 8, den geringsten Rang, ab.

**Tabelle 4.28: Typisches Geruchsmessungsprogramm mit vereinfachten Messungen eines nicht näher genannten Betriebs, in dem Nahrungsmittel hergestellt werden [34, Willey A R and Williams D A, 2001]**

Mittels der Modellierung der Ausbreitung in der Luft lässt sich die Auswirkung der wesentlichsten gemessenen Emissionen eventuell vollständig quantifizieren. Als Auswirkung in diesem Sinne gilt die sich ergebende Geruchskonzentration am Boden aus den Gesamtemissionen des Standorts in verschiedenen Abständen zur Grenze des Betriebsgeländes, bezogen auf die meteorologischen Bedingungen. Hieraus ergeben sich dann ggf. die erforderlichen Maßnahmen zur Begrenzung von Geruchsemissionen. Wenn es verschiedene Gerüche oder Komponenten aus derselben Quelle gibt, was normalerweise der Fall ist, können diese alle zusammen betrachtet werden. Wenn es mehr als eine Geruchsquelle gibt, so müssen alle Quellen einzeln betrachtet werden.

#### 4.4.1.4 Schritt 4: Auswahl von Techniken für die Begrenzung von Luftemissionen

Durch eine Bestandsaufnahme von Emissionen, Immissionen und Beschwerden, z. B. im Fall von Gerüchen, die oft durch die Emission von VOC bedingt sind, können die Hauptquellen für Luftemissionen eines Standorts identifiziert werden, die in den Minderungsplan bzw. die Minderungsstrategie einbezogen werden müssen. So können alle Quellen, deren Auswirkungen beseitigt oder zumindest gemindert werden können, festgestellt werden. Es gibt prozessintegrierte und nachgeschaltete („end-of-pipe“) Verfahren.

Zu den prozessintegrierten Behandlungen zählen stoffbezogene Maßnahmen, wie z. B. die Auswahl von Ersatzstoffen für schädliche Stoffe wie Karzinogene, Mutagene oder Teratogene, oder die Verwendung von emissionsarmen Materialien, wie Flüssigkeiten mit geringer Flüchtigkeit und Feststoffen mit geringer Staubbildung. Außerdem fallen darunter prozessbezogene Maßnahmen, wie die Verwendung von emissionsarmen Systemen und Produktionsprozessen. Wenn nach der Anwendung prozessintegrierter Maßnahmen immer noch eine Emissionssenkung erforderlich ist, kann die Anwendung nachgeschalteter Techniken zur weiteren Begrenzung der Emission von Gasen, Gerüchen/VOC und Staub notwendig sein.

#### 4.4.2 Prozessintegrierte Techniken

Prozessintegrierte Verfahren zur Minimierung der Luftemissionen haben im Allgemeinen einen weiteren Umweltnutzen, wie beispielsweise die optimierte Nutzung von Rohmaterial und die Minimierung der Abfallentstehung. Diese Umweltvorteile sind in diesem Kapitel aufgeführt, wenn sie mit einer Technik in Verbindung stehen. Einige der als Verfahren zur Minderung von Luftemissionen beschriebenen Techniken sind auch in den Prozess integriert und ermöglichen die Rückgewinnung von Material zur Wiederverarbeitung, z. B. Zyklone (siehe Abschnitt 4.4.3.5.2).

#### 4.4.3 Nachgeschaltete Luftbehandlung

In den Abschnitten 4.4.3.1 bis 4.4.3.13 werden nachgeschaltete Techniken, die zur Behandlung von Luftemissionen in der Nahrungsmittelproduktion eingesetzt werden, beschrieben. Kapitel 2 deckt die Prozessarbeitsgänge in der Nahrungsmittelproduktion ab, beschreibt aber keine nachsorgenden Behandlungstechniken.

Nachgeschaltete Maßnahmen sind darauf ausgelegt, nicht nur die Massenkonzentrationen, sondern auch die Massenströme der Schadstoffe in der Luft, die bei einem Arbeitsgang oder Prozess entstehen, zu verringern. Sie werden während des Normalbetriebs der Anlage angewandt.

In Tabelle 4.29 sind Beispiele weitverbreiteter Abgasreinigungstechniken zur Verminderung der Luftverschmutzung aufgeführt.

| Behandlungsprozesse  |                                       |
|--|---------------------------------------|
| Feste und flüssige Schadstoffe   | Gasförmige Schadstoffe und Geruch/VOC |
| Dynamische Trennung  | Absorption                            |
| Nasse Trennung   | Kohlenstoffadsorption                 |
| Elektrostatische Abscheidung   | Biologische Behandlung                |
| Filtration   | Thermische Behandlung                 |
| Trennung von Aerosolen/Tropfchen*  | Nicht-thermische Plasmabehandlung     |
|  | Kondensation*                         |
|  | Membrantrennung*                      |
| *In diesem Dokument nicht als Technik zur Minimierung von Luftemissionen beschrieben |                                       |

**Tabelle 4.29: Nachsorgende Techniken zur Verminderung von Luftverschmutzungen**  
[34, Willey A R and Williams D A, 2001, 65, Germany, 2002]

Bei der Abscheidung dispergierender Teilchen/Stäube werden äußere Kräfte, d. h. in erster Linie die Schwerkraft, die Trägheitskraft und die elektrostatische Kraft genutzt. Die Ableitung über Schornsteine und die Erhöhung des Dispersionspotenzials durch die Erhöhung des Schornsteins oder eine größere Ausstoßgeschwindigkeit werden ebenfalls praktiziert.

Die Eigenschaften der Emission bestimmen die Auswahl der am besten geeigneten Abgasreinigungstechnik zu deren Minderung. Dabei kann etwas Flexibilität erforderlich sein, damit auch die Behandlung später erkannter Quellen möglich ist. Tabelle 4.30 zeigt die Schlüsselparameter für das Auswahlverfahren.

| Parameter                                       | Einheit                |
|---|------------------------|
| Volumenstrom                                    | m <sup>3</sup> /Stunde |
| Temperatur                                      | °C                     |
| Relative Luftfeuchte                            | %                      |
| Typischer Bereich der vorliegenden Bestandteile | –                      |
| Staubkonzentration                              | mg/Nm <sup>3</sup>     |
| Konzentration organischer Verbindungen          | mg/Nm <sup>3</sup>     |
| Geruchskonzentration                            | GE/Nm <sup>3</sup>     |

**Tabelle 4.30: Schlüsselparameter für die Auswahl der nachsorgenden Technik**

In manchen Fällen lassen sich die Bestandteile der Emission leicht identifizieren. Im Fall von Gerüchen enthält die zu behandelnde Emission üblicherweise eine komplexe Mischung und nicht nur ein oder zwei leicht bestimmbar Bestandteile. Die Anlage zur Verminderung der Luftbelastung wird daher oft auf der Basis von Erfahrungen mit ähnlichen Produktionsstätten geplant. Durch die Unsicherheit, die sich aus dem Vorhandensein einer erheblichen Zahl luftgetragener Bestandteile ergibt, können Versuche mit Pilotanlagen nötig werden. Der zu behandelnde Volumenstrom ist ein wesentlicher Parameter im Auswahlverfahren, und sehr oft werden Techniken zur Minderung der Luftemissionen nach dem optimalen Volumenstrombereich für ihre Anwendung aufgelistet.

Beim Erwerb einer Anlage zur Abgasreinigung ist üblicherweise auch eine Reihe von Garantieerklärungen, z. B. hinsichtlich der mechanischen und elektrischen Zuverlässigkeit für einen Zeitraum von mindestens einem Jahr, eingeschlossen. Im Rahmen des Auswahl- und Beschaffungsverfahrens wird der Lieferant auch Angaben zur Beseitigungseffizienz des Prozesses benötigen. Die Form der Prozessgarantie bildet einen wichtigen Bestandteil des Vertrags. So können zum Beispiel die Garantieerklärungen hinsichtlich der Geruchsbeseitigungsleistung eine Reihe verschiedener Formen annehmen. Liegen keine olfaktometrischen Daten vor, bezieht sich die Garantie möglicherweise einfach auf „keine wahrnehmbaren Gerüche außerhalb der Prozessgrenzen oder außerhalb des Betriebsgeländes.“

Äußerst hohe Standards für Abscheidegrade von Partikeln im Abgas lassen sich mit zweiphasigen Konzepten einer Hochleistungsabscheidetechnik erzielen, z. B. durch die Verwendung von zwei Stofffiltern oder deren Kombination mit HEPA-Filtern (beschrieben im Referenzdokument „Abwasser- und Abgasbehandlung/-management“ [217, EC, 2003] oder mit Elektrofiltern (ESP-Filtern).

Tabelle 4.31 zeigt einen Leistungsvergleich von Abscheidetechniken.

| Technik                    | Teilchengröße $\mu\text{m}$ | % Abscheidungsgrad bei $1 \mu\text{m}$ | Maximale Betriebstemperatur in $^{\circ}\text{C}$ | Bereich der erzielbaren Emissionskonzentrationen in $\text{mg}/\text{Nm}^3$ | Anmerkungen   |
|----------------------------|-----------------------------|--|---|---|---|
| Zyklon                     | 10                          | 40*                                    | 1.100   | 25 – 100  | Grobe Teilchen. Zur Unterstützung anderer Verfahren eingesetzt        |
| Nassabscheidung            | 1 – 3                       | >80 – 99                               | Zufuhr 1000<br>Abgabe 80                          | <4 – 50   | Gute Leistung bei geeigneten Staubarten. Reduktion saurer Gase        |
| Trocken-ESP                | <0,1                        | >99<br>je nach Auslegung               | 450   | <5 – 15<br>(vor Behandlung > 50)  | Vier oder fünf Zonen. Wird üblicherweise vor der Behandlung angewandt |
| Nass-ESP                   | 0,01                        | <99                                    | 80  | <1 – 5<br>optisch klar  | ESP mit zwei Zonen in Reihe. Hauptsächlich Sprühnebelniederschlag     |
| Filtration – Gewebefilter  | 0,01                        | >99,5                                  | 220   | <1 – 5  | Gute Leistung bei geeigneten Staubarten                               |
| Filtration – Keramikfilter | 0,01                        | 99,5                                   | 900   | 0,1 – 1   | Sehr gute Leistung bei geeigneten Staubarten                          |

\* Bei größeren Partikeln und hocheffizienten Zyklonen können Auffangeffizienzen von etwa 99 % erzielt werden.

Tabelle 4.31: Abscheidungstechniken im Vergleich

#### 4.4.3.1 Optimaler Einsatz von Abgasreinigungstechniken

##### Beschreibung

Die Anforderungen an die einzusetzenden Geräte zur Abgasreinigung können von der Rezeptur abhängig sein, z. B. im Fall von Geruch. Wenn es Prozesse oder Rezepturen gibt, bei denen die Geräte zur Abgasreinigung nicht die ganze Zeit laufen müssen, so kann das Gerätemanagement darauf ausgerichtet sein, dass sie bei Bedarf bei den erforderlichen Betriebsbedingungen zur Verfügung stehen.

Die Geräte können so installiert werden, dass sie vom jeweiligen Bediener nicht ausgeschaltet werden können, dass jedoch in Fällen, in denen keine Abgasreinigung erforderlich ist, das Management sie ausschalten kann. So kann beispielsweise das Führungspersonal die Schlüssel verwahren, die den Zugang zu den Steuerelementen ermöglichen, mit denen die Geräte ausgeschaltet werden können. Das Führungspersonal ist dann auch dafür zuständig, dass die Geräte rechtzeitig wieder eingeschaltet werden, damit sie im Bedarfsfall ihre optimalen Betriebsbedingungen erreicht haben.

##### Erreichbare Umweltvorteile

Geringere Emissionen in die Luft.

##### Betriebsdaten

In einer Beispielanlage, in der feuchtes Tierfutter in Dosen abgefüllt wurde, wurden keine übelriechenden Substanzen freigesetzt. Mit der Herstellung eines neuen Produkts kam es jedoch zu erheblichen Geruchsproblemen, da die bestehenden Maßnahmen zur Geruchsminderung nicht für das neue Produkt geeignet waren. Rezepturumstellungen führen auch zu sich ändernden Geruchsproblemen in Tierfutttermöhlen, in denen chargenweise Fischöl oder Melasse zugesetzt werden. Diese Beispiele illustrieren den schwankenden Geruchsminderungsbedarf sogar innerhalb derselben Anlage.

Damit Emissionen in die Luft effizient vermieden werden können, muss nicht nur sichergestellt sein, dass die entsprechenden Geräte eingeschaltet sind, sondern dass auch die entsprechenden Betriebsbedingungen gegeben sind. So arbeiten beispielsweise thermische Nachverbrennungsanlagen, wie sie in Fleisch- und Fischräuchereien und in Kaffeeröstereien zur Geruchsbeseitigung durch thermische Oxidation eingesetzt werden, erst ab der Verbrennungstemperatur der Schadstoffe effizient. Die Nachverbrennungsanlagen müssen also rechtzeitig hochgefahren werden, damit diese Temperaturen in der Verbrennungskammer erreicht werden (siehe Abschnitte 4.4.3.11.1 und 4.4.3.11.3).

### Anwendbarkeit

Anwendbar, wo Abgasreinigungsverfahren verwendet werden.

### Anlass für die Umsetzung

Vermeidung von Luftemissionen.

### Referenzliteratur

[182, Germany, 2003, 234, UK, 2003, 235, DG Environment, 2003]

#### **4.4.3.2 Erfassen von Luftemissionen an der Quelle – örtliche Luftabzüge**

##### Beschreibung

Die ausreichende Belüftung des Arbeitsplatzes und spezifischer Arbeitsabläufe ist erforderlich, um geeignete Arbeitsbedingungen zu sichern, Sauerstoff für die Verbrennung in öl- oder gasbefeueten Geräten zu liefern und auch als Teil des Systems, mit dem die Emissionen in die Luft begrenzt werden. Allgemeine und örtliche Belüftung beseitigt beispielsweise die Verbrennungsprodukte von öl- und gasbefeueten Geräten sowie Gerüche, Dämpfe und Wasserdampf von Garungsprozessen.

Örtliche Abzugslüftung kann vor gesundheitsschädlichen Garungsdämpfen, die z. B. bei der direkten Anwendung von Wärme auf das Nahrungsmittel entstehen, schützen. Wenn solche Belüftungsvorrichtungen nicht dafür ausgelegt sind, sauber und frei von Fettresten zu bleiben, können sie an Effizienz verlieren und zu Brandrisiken werden. Wenn die eingeblasene Austauschluft zu heiß oder zu kalt ist, besteht das Risiko, dass Mitarbeiter die Belüftung ausschalten. Wenn die Luft auf natürliche Weise angesaugt wird, ist es meist erforderlich, das Eindringen von Schädlingen zu verhindern. Die abgezogene Luft kann an eine Anlage zur Vermeidung von Luftemissionen abgegeben werden. In manchen Fällen ist unter Berücksichtigung der Hygieneanforderungen auch eine Rückführung möglich. In manchen Anwendungen kann luftgetragenes Material für die Wiederverwendung aufgefangen werden.

Wenn Luftemissionsquellen nach außen abgeschlossen und örtliche Abzugslüftung eingesetzt werden, wird deutlich weniger Energie verbraucht als bei der Behandlung des gesamten Raumvolumens. Zu den Luftemissionen zählen beispielsweise Gerüche, die oft durch VOC-Emissionen entstehen, und Stäube, z. B. von Getreide und Mehl. Um effektiv zu sein, muss die Saugkapazität angemessen sein, und Einrichtungen wie Führungsplatten und Schüttgutbehälter mit Schwingklappen und Deckeln können zur Minimierung von Staub- und Gasemissionen beitragen.

Die Emissionen, die eine Behandlung erfordern, werden an ihrem Ursprung in Leitungen aufgenommen und, soweit möglich, zusammengeführt, bevor sie zu einer Abgasreinigungseinrichtung weitergeleitet werden.

Das Ziel dieser Vorrichtungen ist es, das Entweichen von Luftemissionen möglichst zu verhindern oder auf ein Minimum zu beschränken. Die folgenden Bereiche sind dabei besonders zu beachten:

- Bereiche zum Be- und Entladen von Fahrzeugen
- Zugangsstellen zur Prozessanlage
- offene Förderbänder
- Lagergefäße
- Transferprozesse
- Füllprozesse
- Abgabeprozesse.

##### Erreichbare Umweltvorteile

Weniger Luftemissionen und potenzielle Wiederverwendung luftgetragener Materialien.

##### Medienübergreifende Auswirkungen

Energieverbrauch.

##### Betriebsdaten

Die Mehrzahl der Techniken zur Minderung von Luftemissionen wird gemäß dem zu behandelnden Luftstromvolumen geplant. Das erfordert die effektive Eindämmung der einzelnen Emissionen, wobei gleichzeitig eine

ausreichende Umluftrate aufrechterhalten werden muss, damit keine Luftemissionen in die Arbeitsumgebung gelangen.

Beispiele für die Rückführung von Luft sind u. a.:

- Rückführung von Kaffeeröstgasen aus der kontinuierlichen oder nicht kontinuierlichen Röstung
- Staubführende Zufuhrluft kann zu pneumatischen Fördervorrichtungen zurückgeführt werden, wobei auch der Staub für die Wiederverwendung aufgefangen wird
- Der Rauch aus Räucherkammern kann teilweise oder vollständig zurückgeführt werden.

Unterlagen zu Planungskriterien, Leistungstests, Wartungsanforderungen sowie Tests und Inspektionen können die zukünftige Wartung, Veränderungen und Tests im Vergleich zu den Originaldaten erleichtern.

#### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion mit Emissionen in die Luft, z. B. beim Be- und Entladen von Fahrzeugen, an Schüttgutbehältern, Transferpunkten, Schütten und Beladerohren.

#### Wirtschaftliche Aspekte

Wenn der Abluftstrom minimiert wird, lassen sich die Investitionskosten für die Anlage zur Vermeidung der Luftemissionen erheblich senken. Es ist wichtig, zwischen der allgemeinen Belüftung der Anlage und örtlicher Abzugslüftung zu unterscheiden. Die allgemeine Belüftung erfordert die Bewegung erheblich größerer Luftmengen, benötigt also mehr Energie und ist teurer.

#### Anlass für die Umsetzung

Gesundheit am Arbeitsplatz.

#### Referenzliteratur

[34, Willey A R and Williams D A, 2001, 65, Germany, 2002, 233, Health and Safety Executive, 2000]

### **4.4.3.3 Transport der Emissionen in Leitungen zur Behandlungs- oder Minderungseinrichtung**

#### Beschreibung

Die Emissionen werden in Leitungen zur nachgeschalteten Behandlung oder zur Abgasreinigungsanlage transportiert. Bei der Planung von Vorrichtungen für den Transport von Emissionen zur Behandlungsanlage sind drei wichtige Faktoren zu berücksichtigen, nämlich Transportgeschwindigkeit, Planung der Leitungen für die Belüftung sowie nicht kontinuierliche Ströme.

#### Erreichbare Umweltvorteile

Geringere Luftemissionen.

#### Medienübergreifende Auswirkungen

Energieverbrauch.

#### Betriebsdaten

Der Transport von Emissionen in Leitungen zur Behandlungsanlage muss sorgfältig geplant werden, um Probleme beim Betrieb zu vermeiden. Insbesondere potenzielle Ablagerungen von Partikeln und potenzielle Kondensation von Wasser und anderen luftgetragenen Verunreinigungen können zu starken Verschmutzungen führen, die häufige Reinigungen erfordern und Hygieneprobleme verursachen können. Wenn Reinigungspunkte und Ablassventile in die Belüftungsleitungen eingebaut werden, lässt sich angelagertes Material beim Reinigen entfernen.

Durch die Wahl einer niedrigen Transportgeschwindigkeit werden die Kosten für das Abzugsgebläse gesenkt. Wenn Staub als eines der vorliegenden Probleme gilt, wird eine Transportgeschwindigkeit nicht unter 10 m/s gewählt. Als Minimum gilt eine Transportgeschwindigkeit von 5 m/s.

Wenn das Vorhandensein von Staub trotz hoher Transportgeschwindigkeiten Probleme im Betrieb erwarten lässt, kann eine Absetzkammer installiert werden. Dabei handelt es sich um eine erweiterte Leitung, in die die mit Partikeln beladenen Luftströme eintreten, und in der die Gesamtgeschwindigkeit auf 2,5 bis 5,0 m/s zurückgeht. Die Kammer ist absichtlich so konstruiert, dass sie die Ablagerung von Partikeln fördert, und an

einer Seite mit Trichtern und einer Reihe von über die gesamte Länge verteilten Reinigungsklappen versehen. Am Ende der Absetzkammer verringert sich der Durchmesser der Leitung dann wieder, sodass die Transportgeschwindigkeit des Systems erneut erreicht wird.

Die zusätzlichen Belüftungsleitungen werden mit einer gemeinsamen Transportgeschwindigkeit geplant, sodass die Luftgeschwindigkeit in allen Leitungs- und Auslassrohren gleich ist. Der Eintritt von Rohren in die Hauptleitung kann einen Winkel von bis zu 45° haben, wobei jedoch ein Winkel von 30° effizienter ist. Am Eintrittspunkt eines Rohres in die Hauptleitung nimmt der Durchmesser der Hauptleitung allmählich mit einem Winkel von 15° zu. Um zu gewährleisten, dass die erforderliche Leistung auch erzielt wird, erfolgt die Planung des Lüftungsleitungssystems häufig durch ein entsprechend spezialisiertes Unternehmen.

Diskontinuierliche Abluftströme sind recht häufig, wenn eine Reihe von Abzügen in eine zentrale Behandlungsanlage geleitet wird, falls einige kontinuierlich und andere diskontinuierlich sind. Dadurch können bestimmte Abzüge andere Prozessemissionen während eines Ausfalls kontaminieren, und der Betrieb des Gebläses bei unterschiedlichen Belastungen muss berücksichtigt werden.

Für eine solche Anordnung kann ein kompliziertes Steuersystem erforderlich sein. So kann beispielsweise das Gebläse als System mit nur einer Umdrehungszahl ausgelegt sein, sodass es immer den gleichen geplanten Volumenstrom erzeugt. Ein solches System erfordert einen zusätzlichen Zustrom zum Belüftungssystem, um den geplanten Volumenstrom selbst dann aufrecht zu erhalten, wenn ein Prozess abgeschaltet wird. Dieser zusätzliche Zustrom könnte vom Arbeitsplatz des Bedieners oder von der zusätzlichen Belüftung des Gebäudes abgezogen werden. Alternativ kann ein Gebläse mit Frequenzumrichter verwendet werden. Die Gebläsedrehzahl wird dann durch eine statische Druckmessung an der Luftzufuhr zum Gebläse und hinter dem letzten Eintritt eines Rohres gesteuert. Bei diesem System ist der Volumenstrom zur Behandlungsanlage gemäß den jeweiligen in Betrieb befindlichen Prozessen variabel. Ob man ein System mit fester Umdrehungszahl oder ein Umrichtersystem wählt, hängt zum großen Teil davon ab, welche Art von Abgasreinigungsanlage installiert wurde, und ob es bei einem veränderlichen Volumenstrom Nachteile in der Behandlungseffizienz gibt.

### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion, bei denen Emissionen in die Luft auftreten.

### Referenzliteratur

[34, Willey A R and Williams D A, 2001]

#### **4.4.3.4 Auswahl von nachgeschalteten Techniken zur Minderung von Gerüchen/VOC**

##### Beschreibung

Bei der Auswahl von Geruchsminderungstechniken besteht der erste Schritt in der Untersuchung von Volumenstrom, Temperatur, Feuchtigkeit sowie von Partikel- und Verunreinigungskonzentrationen der übelriechenden Emissionen. Gerüche entstehen oft durch VOC-Emissionen; dann müssen bei der angewandten Minderungstechnik Gefahren durch Toxizität und Brennbarkeit berücksichtigt werden. Eine Zusammenfassung der allgemeinen Kriterien für die Auswahl von Geruchs-/VOC-Minderungstechniken ist in Tabelle 4.32 zu finden, in der diese Parameter als Matrix in Bezug auf einige allgemeine Minderungsvorrichtungen eingetragen sind. Tabelle 4.32 ist als Richtschnur zu verstehen und enthält nicht die vollständigen Angaben zu Vorteilen und Einschränkungen der einzelnen Techniken. Jede Eigenschaft der übelriechenden Emissionen ist in zwei oder drei Bereiche unterteilt. In diesem Beispiel wurde der Volumenstrom in zwei Bereiche, nämlich ober- und unterhalb von 10.000 m<sup>3</sup>/h, unterteilt. Jeder Zelle in der Matrix wurde ein Wert zwischen 0 und 3 zugeordnet, wobei 3 den optimalen Betriebsbedingungen entspricht.

Für jede der Minderungstechniken ist der relevante Bereich jeder der Eigenschaften der übelriechenden Emissionen aufaddiert. Dadurch wird ein einfaches System zur Rangfolgenbildung erstellt, in dem die Techniken mit den höchsten Werten weiter untersucht werden. Üblicherweise werden dann drei bis fünf Minderungstechniken in den nächsten Schritt des Auswahlverfahrens übernommen.

| Behandlung             | Volumenstrom (m <sup>3</sup> /Stunde)  |         | Temperatur (°C) |     | Relative Luftfeuchte (%) |     | Partikel (mg/Nm <sup>3</sup> ) |     | Rohgas-konzentration (mg/Nm <sup>3</sup> ) |      |      | Wert |
|------------------------|--|---------|-----------------|-----|--------------------------|-----|--------------------------------|-----|--|------|------|------|
|                        | <10.000  | >10.000 | <50             | >50 | <75                      | >75 | 0                              | <20 | >20  | <500 | >500 |      |
| Physikalisch           | 1  | 2       | 1               | 2   | 2                        | 1   | 1                              | 1   | 2  | 1    | 0    |      |
| Absorption – Wasser    | 1  | 1       | 2               | 1   | 2                        | 1   | 1                              | 1   | 3  | 1    | 0    |      |
| Absorption – chemisch  | 2  | 2       | 2               | 1   | 2                        | 1   | 2                              | 1   | 1  | 2    | 1    |      |
| Adsorption             | 3  | 1       | 3               | 0   | 2                        | 0   | 3                              | 0   | 0  | 2    | 1    |      |
| Biologisch             | 3*   | 2*      | 3               | 0   | 2                        | 2   | 3                              | 1   | 0  | 3    | 0    |      |
| Thermische Oxidation   | 3  | 1       | 1               | 3   | 2                        | 1   | 3                              | 2   | 1  | 3    | 3    |      |
| Katalytische Oxidation | 3  | 2       | 1               | 3   | 2                        | 1   | 3                              | 0   | 0  | 3    | 3    |      |
| Plasma                 | 2  | 3       | 3               | 1–2 | 3                        | 2   | 3                              | 3   | 1–2  | 3    | 2    |      |
| <b>Bewertung</b>       | <b>Beschreibung</b>  |         |                 |     |                          |     |                                |     |  |      |      |      |
| 0                      | Diese Behandlung ist nicht geeignet oder wahrscheinlich nicht effektiv, sodass sie im Auswahlverfahren nicht weiter berücksichtigt wird. |         |                 |     |                          |     |                                |     |  |      |      |      |
| 1                      | Weitere Berücksichtigung empfehlenswert, auch wenn es wahrscheinlich nicht die beste Behandlung ist                                      |         |                 |     |                          |     |                                |     |  |      |      |      |
| 2                      | Diese Minderungstechnik ist für diese Situation gut geeignet   |         |                 |     |                          |     |                                |     |  |      |      |      |
| 3                      | Beste Betriebsbedingung für das jeweilige Behandlungssystem  |         |                 |     |                          |     |                                |     |  |      |      |      |
| *                      | Abhängig vom Oberflächenbereich  |         |                 |     |                          |     |                                |     |  |      |      |      |

**Tabelle 4.32: Zusammenfassung allgemeiner Kriterien für die Auswahl von Geruchs-/VOC-Minderungstechniken**

Als nächstes wird die Effektivität bzw. die benötigte Leistung betrachtet. Hierzu werden professionelle Beratung und Informationen vom Hersteller der Minderungstechniken benötigt.

Der nächste Schritt im Verfahren ist eine Machbarkeitsbewertung. Investitions- und Betriebskosten, Platzbedarf und Erfahrungswerte für die Anwendbarkeit der Minderungstechnik in vergleichbaren Prozessen werden berücksichtigt.

Abbildung 4.23 zeigt ein Flussdiagramm, mit dem dieses Verfahren zur Auswahl von nachgeschalteten Techniken zur Minderung von Gerüchen/VOC zusammenfassend dargestellt wird.

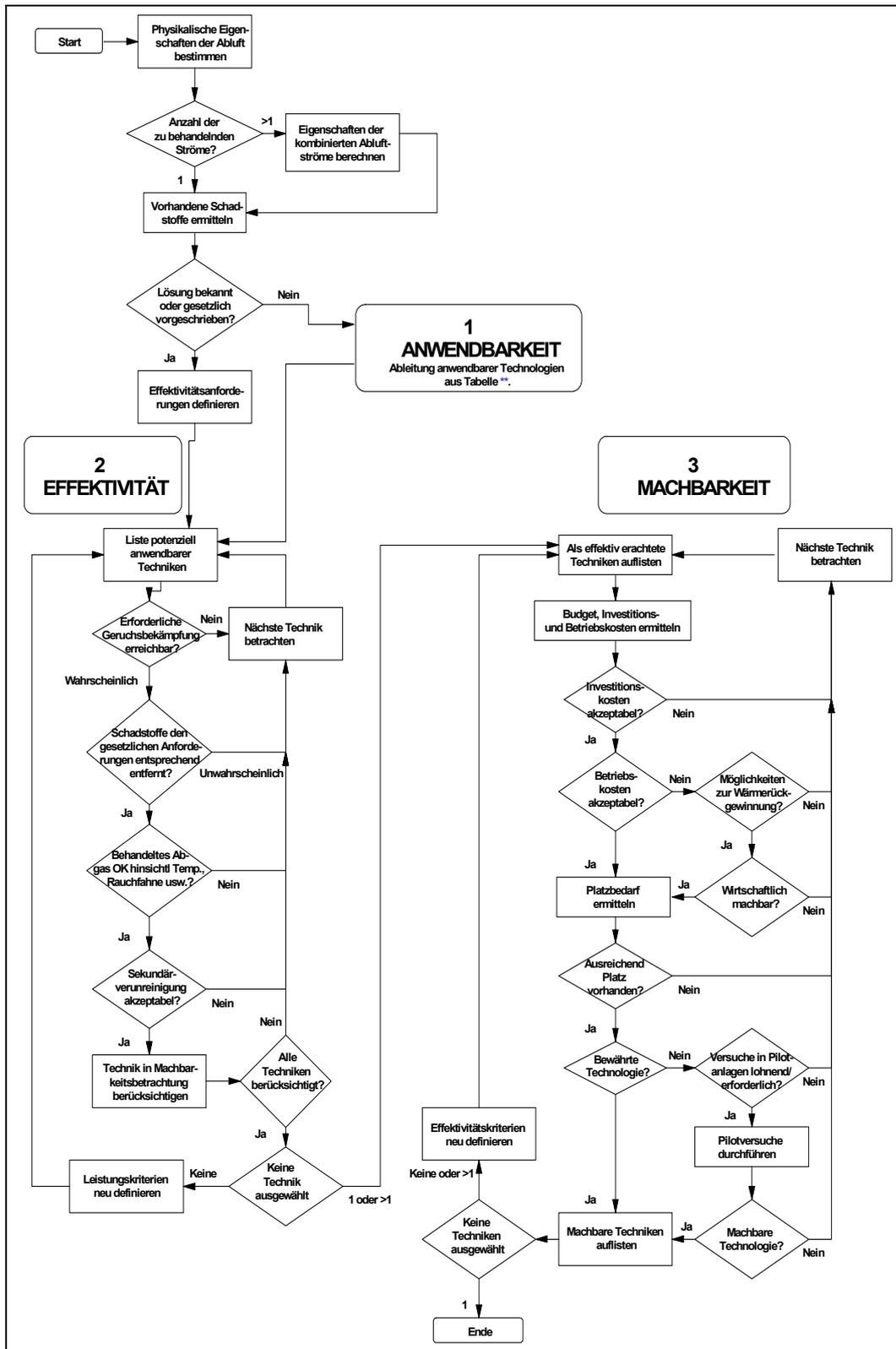


Abbildung 4.23: Flussdiagramm zur Auswahl von Geräten und Ausrüstungen zur Geruchsminderung (\*\*siehe Tabelle 4.32)

Erreichbare Umweltvorteile  
 Verringerte Geruchsemissionen.

Anwendbarkeit  
 In allen Anlagen der Nahrungsmittelproduktion anwendbar.

Anlass für die Umsetzung

Verringerte Geruchsemissionen.

Referenzliteratur

[34, Willey A R and Williams D A, 2001]

**4.4.3.5 Schwerkraftabscheider**

Die Grundlage für die Abscheidung und Entfernung von Partikeln in dynamischen Abscheidern sind die Feldkräfte, die zur Partikelmasse proportional sind. Daher sind Schwerkraftabscheider, Ablenk- oder Massenkraftabscheider und Zentrifugalabscheider wie Zyklone, Mehrfachzyklone und Drehströmungsentstauber allesamt dynamische Abscheider. Sie werden hauptsächlich für die Abscheidung großer Partikel ( $> 10 \mu\text{m}$ ) oder als erster Schritt vor der Entfernung von Feinstäuben durch andere Mittel eingesetzt.

**4.4.3.5.1 Massenkraftabscheider**Beschreibung

Der Abgasstrom wird in eine Kammer geleitet, wo Staub, Aerosole und/oder Tröpfchen unter dem Einfluss von Schwerkraft/Massenträgheit vom Gas abgeschieden werden. Die Wirkung wird durch bauliche Mittel wie z. B. Prallbleche, Lamellen oder Metallgaze verstärkt, die die Gasgeschwindigkeit verringern.

Die Bauart sollte eine gute, gleichmäßige Geschwindigkeitsverteilung innerhalb des Behälters gewährleisten. Bevorzugte Strömungsbahnen beeinträchtigen die Effizienz. Der Einsatz interner Hindernisse im Massenkraftabscheider ermöglicht den Betrieb bei höheren Geschwindigkeiten, wodurch der Abscheider im Vergleich zur Absetzkammer ein kleineres Volumen haben kann. Der Nachteil dagegen ist der stärkere Druckabfall. Weitere Angaben finden sich im Referenzdokument „Abwasser- und Abgasbehandlung/-management“ [217, EC, 2003].

Erreichbare Umweltvorteile

Weniger Schadstoffe in Luftemissionen. Potenzielle Wiederverwendung luftgetragenen Materials.

Medienübergreifende Auswirkungen

Energieverbrauch.

Betriebsdaten

Abscheider sind durch einfache und robuste Bauart, geringen Platzbedarf und hohe Betriebszuverlässigkeit gekennzeichnet.

Ablenk- oder Massenkraftabscheider ermöglichen die effektive Abscheidung von Stäuben. Aufgrund ihrer Massenträgheit können größere Partikel dem mehrfach umgelenkten Gasstrom nicht folgen und werden abgeschieden. Bei entsprechender Bauart lassen sich für Partikel, die größer sind als  $100 \mu\text{m}$ , Abscheidegrade von 50 % erzielen.

Anwendbarkeit

Abscheider sind unter folgenden Bedingungen einsetzbar:

- hohe Staubkonzentrationen im unbehandelten Gas
- Entfernung feiner Partikel nicht erforderlich
- vorgeschaltete Abscheidung und/oder Schutz und Entlastung nachgeschalteter Systeme erforderlich
- hohe Drücke, z. B. bei der Hochdruckentstaubung
- hohe Temperaturen, z. B. bei der Hochtemperaturentstaubung

Wirtschaftliche Aspekte

Die Technik ist mit geringen Kosten verbunden.

Referenzliteratur

[65, Germany, 2002]

### 4.4.3.5.2 Zyklone

#### Beschreibung

Zyklone nutzen die Massenträgheit zur Entfernung von Partikeln aus dem Gasstrom durch Zentrifugalkräfte, meist in einer konischen Kammer. Ihr Funktionsprinzip beruht auf der Erzeugung eines doppelten Wirbels innerhalb des Zyklonkörpers. Das einströmende Gas wird in eine Kreisbewegung nach unten nahe der inneren Oberfläche des Zyklonrohrs versetzt. Am Boden wird das Gas umgelenkt und bewegt sich spiralförmig durch die Rohrmitte nach oben, wo es aus dem Zyklon austritt. Im Gasstrom befindliche Partikel werden durch die Zentrifugalkraft des rotierenden Gases an die Zyklonwände gedrückt, wobei ihnen jedoch die Strömungskraft des Gases entgegenwirkt, das durch den Zyklon strömt und diesen verlässt. Große Partikel erreichen die Zyklonwand und werden in einem Trichter am Boden aufgefangen, während kleine Partikel den Zyklon zusammen mit dem austretenden Gas verlassen. Weitere Angaben finden sich im Referenzdokument „Abwasser- und Abgasbehandlung/-management“ [217, EC, 2003].

#### Erreichbare Umweltvorteile

Weniger Schadstoffe in Luftemissionen. Potenzielle Wiederverwendung luftgetragenen Materials.

#### Medienübergreifende Auswirkungen

Energieverbrauch.

#### Betriebsdaten

Zyklone sind durch einfache und robuste Bauart, geringen Platzbedarf und hohe Betriebszuverlässigkeit gekennzeichnet.

Zyklone erzielen bessere Abscheideergebnisse als Abscheider (siehe Abschnitt 4.4.3.5.1). Tabelle 4.31 gibt die Leistungsdaten eines Zyklons im Vergleich zu anderen Abscheidetechniken an. Abbildung 4.24 zeigt das Funktionsprinzip eines Zyklons.

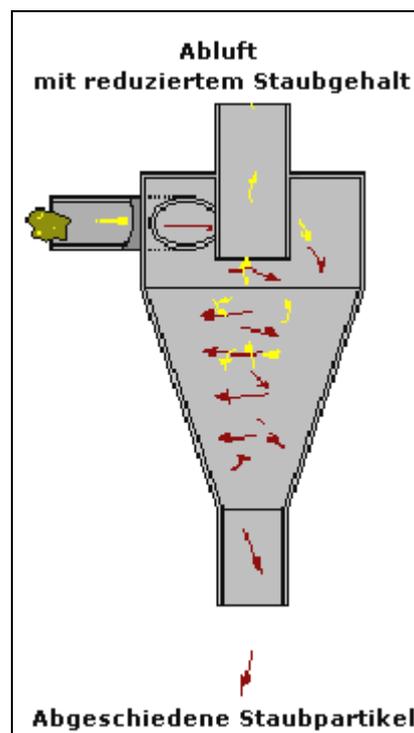


Abbildung 4.24: Funktionsprinzip eines Zyklons

Angaben zufolge werden Zyklone bei der Herstellung von getrockneter Getreideschlempe (Distillers Dried Grains) zur Entfernung kleiner Partikel aus der Abluft vom Trockner verwendet, und die Effizienz der Zyklone kann je nach Prozessbedingungen und Partikelgröße bis zu 99,97 % erreichen (siehe Abschnitt 4.7.9.7.1).

#### Anwendbarkeit

Zyklone werden hauptsächlich zur Abscheidung von Partikeln verwendet, die größer als 10 µm sind. Es gibt aber auch Hocheffizienzzyklone, die selbst für eine Partikelgröße von nur 2,5 µm ausgelegt sind.

Zyklone, die ohne andere Minderungstechniken eingesetzt werden, sind meist nicht in der Lage, die gesetzlichen Vorgaben hinsichtlich der Luftverschmutzung zu erfüllen, aber sie sind sinnvoll als Vorreiniger für teurere Einrichtungen, die für die Endreinigung eingesetzt werden, wie z. B. Gewebefilter (siehe Abschnitt 4.4.3.7) oder elektrostatische Abscheider (siehe Abschnitt 4.4.3.6). Sie werden häufig nach Sprühtrocknern sowie nach Quetsch-, Mahl- und Kalzinierprozessen eingesetzt. Mit fossilen Brennstoffen befeuerte industrielle Verbrennungsanlagen verfügen meist über Multizyklone, die effizienter sind als einstufige Zyklone und auch Partikel mit  $< 2,5 \mu\text{m}$  abscheiden können.

Zyklone werden zur Abscheidung von festen und flüssigen Schadstoffen aus der Luft eingesetzt. Sie werden hauptsächlich zur Abscheidung größerer Partikel, d. h.  $> 10 \mu\text{m}$ , eingesetzt. Sie sind unter folgenden Bedingungen einsetzbar:

- hohe Staubkonzentrationen im unbehandelten Gas
- Entfernung feiner Partikel nicht erforderlich
- vorgeschaltete Abscheidung und/oder Schutz und Entlastung nachgeschalteter Systeme erforderlich
- hohe Drücke, z. B. bei der Hochdruckentstaubung
- hohe Temperaturen, z. B. bei der Hochtemperaturentstaubung

#### Wirtschaftliche Aspekte

Die Technik ist mit geringen Kosten verbunden.

#### Beispielanlagen

Zyklone werden bei der Herstellung von Tierfutter, Trockenmilch, Trockensuppe, Backmischungen, Pudding, getrockneter Getreideschlempe, getrockneten Zuckerrübenschnitzeln, Speiseeisfertigmischungen, bei der Röstung, Trocknung und Mischung von Kaffee, bei der Mischung von Tee und Malz eingesetzt und tragen hier wesentlich dazu bei, Stäube aus der abgesaugten Luft für die Wiederverarbeitung rückzugewinnen. Sie werden bei pflanzlichen Ölen eingesetzt, um feine Verunreinigungen wie Pflanzenrückstände, Staub, Sand und feuchten Staubemissionen aus rohen Ölsaaten zu entfernen (siehe Abschnitt 4.7.4.10).

#### Referenzliteratur

[65, Germany, 2002, 179, Gergely, 2003]

#### **4.4.3.5.3 Nassabscheidung**

##### Beschreibung

In Massenkraftabscheider nehmen die wirksamen Massenkkräfte – Schwer-, Zentrifugal- und Trägheitskräfte – mit der Partikelgröße stark ab. Die Vergrößerung der Partikeloberfläche durch Bindung an Waschflüssigkeitströpfchen oder bespülte Oberflächen stellen eine Möglichkeit dar, den Abscheidegrad von Massenkraftabscheidern und anderen Staubabscheidern zu erhöhen.

Dabei ist zu beachten, dass dadurch im allgemeinen nur eine Verlagerung der Schadstoffe aus der Luft ins Wasser erfolgt. Daher sollten für die Wahl nassarbeitender Abscheider besondere Gründe vorliegen, z. B. klebrige oder leicht entzündliche Stäube bzw. eine begründete Staubexplosionsgefahr.

Nach ihrer Bauweise können verschiedene Arten von Nassabscheidern unterschieden werden, z. B.:

- mit Absorption arbeitende Geräte wie Rieseltürme, Sprühwäscher, Schütttschichtabsorber (siehe Abschnitte 4.4.3.7.3 bis 4.4.3.8 und Tabelle 4.33).
- Düsenwäscher, z. B. Hochdruck-/Zweistoff-Düsenwäscher
- Strahlwäscher
- Wirbelwäscher
- Rotationswäscher, Desintegratoren (Hochleistung)
- Venturiwäscher (Hochleistung)

##### Erreichbare Umweltvorteile

Weniger Luftemissionen, z. B. Staub. Potenzielle Wiederverwendung luftgetragener Materialien. Es kann von Vorteil sein, wenn es in der Anlage selbst eine Möglichkeit gibt, die belastete Auffangflüssigkeit wieder zu verwenden. Rückgewinnung des Produkts. In der Verarbeitung pflanzlicher Öle wird beispielsweise der aufgefangene Staub rückgewonnen und kann dem Mehl wieder zugesetzt werden. Verhinderung von Brandrisiken.

### Medienübergreifende Auswirkungen

Energieverbrauch. Es fällt Abwasser an.

### Betriebsdaten

Mit der Nassabscheidung können Abscheidegrade von 80 - 99 % erzielt werden. Bei der Verwendung von Zyklonen können für feuchte Stäube Emissionskonzentrationen von  $<50 \text{ mg/Nm}^3$  erreicht werden. In Tabelle 4.31 sind die Leistungsdaten dieser Technik im Vergleich zu anderen Abscheidetechniken angegeben.

Staubteilchen aus dem unbehandelten Gas werden mit den erheblich größeren Tröpfchen der Auffangflüssigkeit in Berührung gebracht und bleiben an diesen hängen. Sie können dann zusammen mit den Tröpfchen entfernt werden. Die relativ großen staubbeladenen Tröpfchen, die einen Durchmesser zwischen 50 und 200  $\mu\text{m}$  haben, werden üblicherweise mittels Zyklonen oder Lamellenabscheidern aus dem Gasstrom entfernt. Zyklone werden für Belastungen mit schweren Feststoffen und kleine Gasströme eingesetzt. Bessere Abscheidegrade und geringere Druckverluste lassen sich durch die Verwendung von Lamellenabscheidern in Hochleistungs-Separatoranlagen erzielen. Sie bestehen aus vertikal angeordneten Metall- oder Kunststoffplatten. Sie können Teilchen abscheiden, die größer als 10  $\mu\text{m}$  sind.

Es fällt Abwasser an. Die staubbeladene Auffangflüssigkeit kann behandelt und in den Prozess rückgeführt oder durch Verdampfung aufkonzentriert werden. Insbesondere Trocknungsanlagen geben Dämpfe ab, die mit Wasserdampf beladen sind, der unter Umständen nicht nur Schadstoffpartikel, sondern auch Gerüche und gasförmige Schadstoffe enthält. Ein Beispiel für Designstandards, die in Deutschland gemäß DIN-Norm [230, Deutsches Institut für Normung p.v., 2005] eingesetzt werden, ist in Tabelle 4.33 angeführt.

### Anwendbarkeit

Nassabscheider werden zur Abscheidung von festen und flüssigen Schadstoffen aus Luft eingesetzt, z. B.

- von brennbarem oder klebrigem Staub,
- wenn ein Explosionsrisiko besteht,
- für die gleichzeitige Abscheidung oder vorgeschaltete Abscheidung von festen, flüssigen und gasförmigen Schadstoffen,
- für kleine Staubteilchen ( $<0,1 \mu\text{m}$ ).

Wäscher werden in der Nahrungsmittelproduktion z. B. zur Behandlung von VOC, freien Fettsäuren oder Gerüchen aus der Raffination pflanzlicher Öle eingesetzt.

### Wirtschaftliche Aspekte

Die Kosten für die Abwasserbehandlung können erheblich sein, in manchen Fällen sogar höher als für Maßnahmen zur Begrenzung der Staubemissionen.

### Referenzliteratur

[65, Germany, 2002]

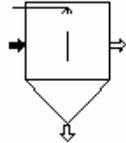
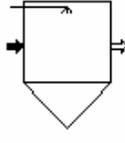
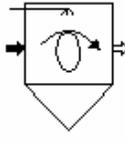
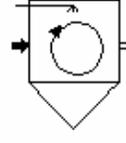
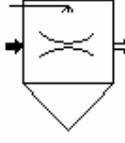
| Beschreibung   | Waschturm<br>Sprühwäscher<br>Füllkörper-<br>kolonne                               | Düsenwäscher, (Hochdruck-<br>/Zweistoff-Düsenwäscher)                              | Strahlwäscher                                | Wirbel-<br>wäscher  | Rotationswäscher,<br>Desintegrator  | Venturiwäscher  |
|--|---|--|--|---|---|---|
| Symbole nach DIN 30600/28004   |  |  |  |  |  |  |
| Gasgeschwindigkeit in der Kontaktzone im Verhältnis zum freien Durchchnitt (m/s)*  | 1 – 5   | 20 – 60  | 5 – 15                                       | 8 – 20  | 25 – 70   | 40 – 150  |
| Druckdifferenz über den gesamten Abscheider (bar)*   | 1 – 25  | 5 – 25   | Druckrück-<br>gewinnung von<br>etwa 1 bis 10 | 15 – 30   | 2 – 10 <sup>(1)</sup>   | 30 – 200  |
| Energiebedarf (kWh/1.000 m <sup>3</sup> )  | 0,2 – 3   | 0,4 – 2  | 1,2 – 3                                      | 1 – 2   | 4 – 15 <sup>(1)</sup>   | 5 – 15  |
| Verhältnis von Waschflüssigkeit zu Gas (l/m <sup>3</sup> )*  | 1 – 5   | 0,5 – 5  | 5 – 50                                       | Bedingt<br>durch<br>Funktions-<br>prinzip<br>keine Daten                            | 1 bis 3 pro Stufe   | 0,5 – 5   |
| Abscheidegrenze (µm)*  | 0,7 – 1,4   | 0,1 – 1  | 0,8 – 0,9                                    | 0,6 – 0,9   | 0,1 – 0,6   | 0,05 – 0,5  |
| Abscheidegrad (%) <sup>(2)</sup>   | 50 – 85   | 90 – 95  | 90 – 95                                      | 90 – 95   | 92 – 96   | 96 – 98   |
| * Anhaltswerte, Abweichungen nach oben und unten möglich   |   |  |  |   |   |   |
| 1) In Desintegratoren ist der Energieverbrauch oft erheblich höher, je nach Effizienz und behandeltem Gasvolumen. Eine Druckrückgewinnung von bis zu 25 bar ist möglich.   |   |  |  |   |   |   |
| 2) Die Abscheidegrad in der Tabelle vermittelt nur eine grobe Vorstellung des möglichen Arbeitsbereichs. Auch wenn die Abscheiderate einfach zu messen ist, lässt sie nur begrenzte Schlussfolgerungen hinsichtlich der Effizienz eines Abscheiders zu. So ist sie beispielsweise direkt von der Partikelgrößenverteilung des zugeführten Materials abhängig. Wenn sich die Partikelgrößenverteilung ändert, ändert sich auch der Abscheidegrad, selbst wenn die übrigen Parameter konstant bleiben. Die Kenntnis des Abscheidegrades ist jedoch für die spezifische Anwendung von Bedeutung. Zur Beurteilung der Effizienz eines Abscheiders ist die Fraktionsabscheiderate viel besser geeignet. |   |  |  |   |   |   |

Tabelle 4.33: Luftentstaubung – Übersicht über Nassabscheider

### 4.4.3.6 Elektrostatische Abscheider

#### Beschreibung

Elektrostatische Abscheider (ESP) werden zur Abscheidung von festen oder flüssigen Partikeln aus Abgasen eingesetzt. Die im Gas verteilten Partikel werden elektrostatisch aufgeladen, sodass sie an Abscheideelektroden haften bleiben.

Die Hauptbestandteile eines ESP sind das Filtergehäuse, die Sprüh- und die Abscheideelektrode, die Stromversorgung, Gasführungsplatten oder Prallbleche und ein Abreinigungssystem für die Reinigung der Abscheideelektroden. Der Abscheideprozess lässt sich in die folgenden Einzelstufen unterteilen:

- Aufladung der Partikel im Ionenfeld
- Transport der geladenen Partikel zur Abscheideelektrode
- Abscheidung und Filmbildung auf der Abscheideelektrode
- Entfernung des Staubfilms von der Abscheideelektrode.

Es ist zwischen trocken und nass arbeitenden ESP zu unterscheiden. Sie können einen horizontalen oder vertikalen Gasstrom aufweisen. Trocken arbeitende ESP werden meist mit Abscheideelektroden in Plattenform hergestellt und werden auch als Platten-ESP bezeichnet. In nass arbeitenden ESP haben die Abscheideelektroden oft Röhrenform; in diesen ist der Gasstrom normalerweise vertikal, und sie werden auch als Röhren-ESP bezeichnet.

#### Erreichbare Umweltvorteile

Verringerung von Luftemissionen. Geringer Energiebedarf im Vergleich zu anderen Abscheidetechniken.

#### Medienübergreifende Auswirkungen

Beim Einsatz nass arbeitender ESP fällt Abwasser an.

#### Betriebsdaten

Elektrostatische Abscheider erlauben Abscheidegrade von bis zu 99,9 %, die effektive Abscheidung von Partikeln, die sogar kleiner als 0,1  $\mu\text{m}$  sind, und die Behandlung eines Abgasvolumens von mehr als 1.000.000  $\text{m}^3/\text{h}$ . Tabelle 4.31 gibt die Leistungsdaten dieser Technik im Vergleich zu anderen Abscheidetechniken an.

Elektrostatische Abscheider weisen relativ geringe Druckabfälle auf, z. B. von 0,001 - 0,004 bar; sie haben einen geringen Energiebedarf, z. B. zwischen 0,05 und 2  $\text{kWh}/1.000 \text{ m}^3$ , und eine lange Lebensdauer. Mit nass arbeitenden ESP können bessere Abscheidegrade als mit trocken arbeitenden ESP erzielt werden. Insbesondere können sie feine Stäube, Aerosole und in gewissem Umfang auch Schwermetalle und gasförmige Substanzen abscheiden.

Abbildung 4.25 stellt den typischen Aufbau eines elektrostatischen Abscheiders dar.

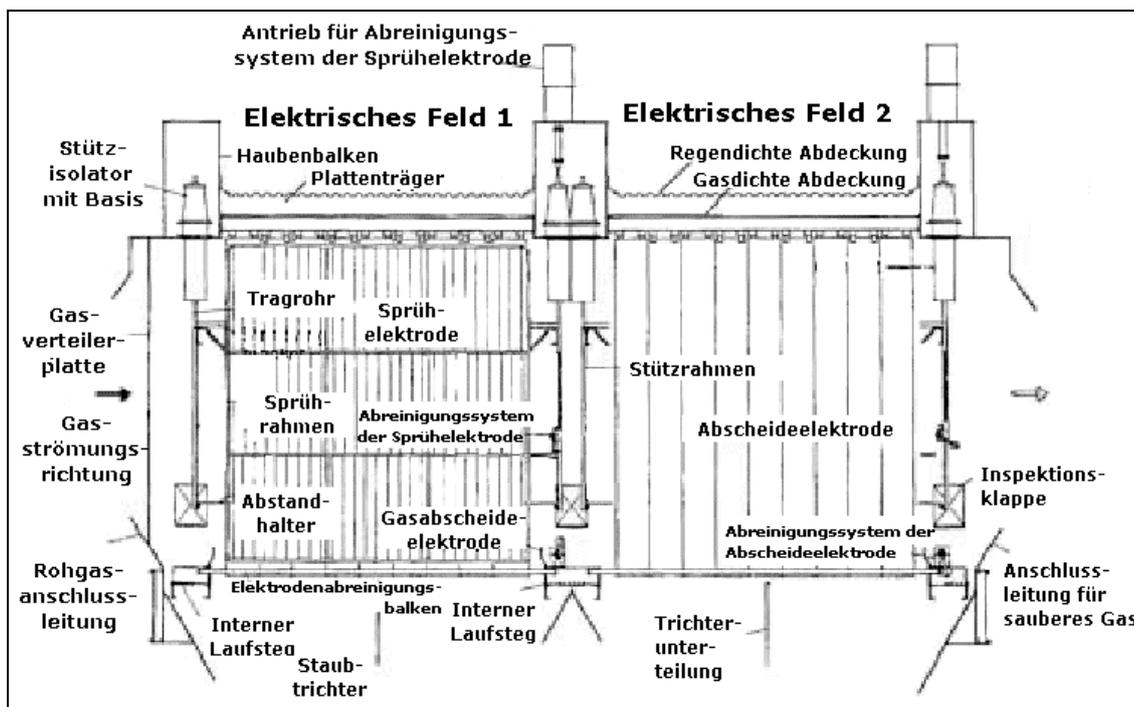


Abbildung 4.25: Typischer Aufbau eines elektrostatischen Abscheiders (nur zwei Zonen dargestellt)

#### Anwendbarkeit

Werden zur Beseitigung von festen und flüssigen Luftschadstoffen, insbesondere für feine Stäube eingesetzt. ESP werden in großen Systemen für die Reinigung großer Abgasmengen bei hohen Temperaturen verwendet. Nass arbeitende ESP werden zur Reinigung von flüssigkeitsgesättigten Gasen, für saure und Teer-Sprühnebel oder bei Explosionsgefahr eingesetzt.

#### Referenzliteratur

[65, Germany, 2002]

#### 4.4.3.7 Filter

Filternde Abscheider werden üblicherweise für die letzte Abscheidestufe eingesetzt, also nach Vorabscheidern, in denen Abgase mit für den Filter schädlichen Bestandteilen abgeschieden werden, z. B. raue Stäube oder aggressive Gase. So werden eine angemessene Lebensdauer und Betriebszuverlässigkeit des Filters gewährleistet.

In filternden Abscheidern wird das Gas durch ein poröses Medium geführt, in dem die verteilten Feststoffpartikel durch verschiedene Mechanismen zurückgehalten werden. Filternde Abscheider können anhand des Filtermediums, des Leistungsbereichs und der Filterreinigungsvorrichtungen, wie sie in Abbildung 4.26 zusammengefasst sind, unterschieden werden.

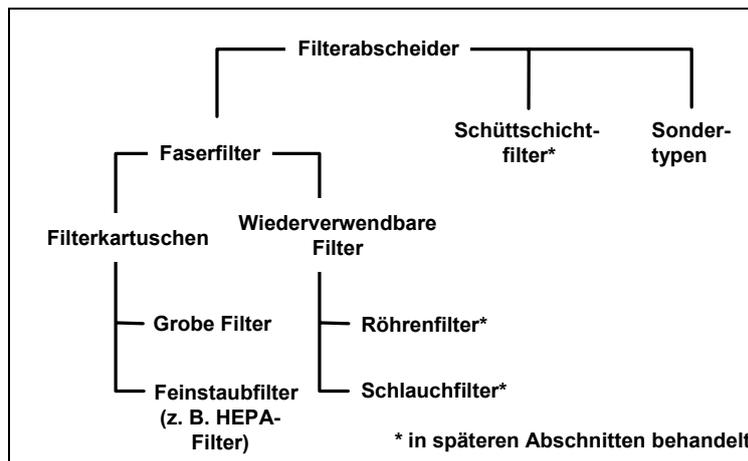


Abbildung 4.26: Arten und Unterteilung von Filtern

In Gewebefiltern wird Abgas durch einen dicht gewebten oder gefilzten Stoff geleitet, wodurch sich der Staub durch Sieb- oder andere Mechanismen auf dem Gewebe ansammelt. Gewebefilter können als Bögen, Kartuschen oder Beutel (häufigster Typ) eingesetzt werden, und es können eine Reihe von Einzelgewebefiltern als Gruppe in einem Gehäuse untergebracht werden. Der sich auf dem Filter bildende Staubkuchen kann die Abscheideeffizienz erheblich steigern.

Abreinigungsfilter gehören zu den wichtigsten Ausführungen filternder Abscheider in der industriellen Entstaubung. Bestand das Filtermedium (Filtermaterial) bei früheren Ausführungen überwiegend aus Gewebe, werden heute vor allem Vliese und Nadelfilze eingesetzt. Wichtigste Kenngrößen sind die Filterflächenbelastung und der Druckverlust.

Das Filtermedium erfüllt die eigentliche Trennfunktion und ist das wesentliche Bauteil eines filternden Abscheiders. Gewebe besitzen rechtwinklig verkreuzte Fäden. Demgegenüber sind Vliese und Nadelfilze dreidimensionale Flächengebilde, die durch die den Fasern eigene Haftung oder durch wechselndes Einstechen und Ausziehen von Nadeln verfestigt werden. Vliese und Nadelfilze können zur Armierung im Innern ein Stützgewebe (z. B. Polyesterfilz oder Glasfasergewebe) enthalten. In zunehmendem Maße setzen sich Nadelfilze aus Kunststofffasern durch.

Vliese und Nadelfilze zeigen tiefenfilternde Eigenschaften. Stäube lagern sich in die Filterstruktur ein, es bildet sich eine Filterhilfsschicht, in der auch kleinste Partikel gut abgeschieden werden. Diese sogenannte Tiefenfiltration zeichnet sich durch eine große wirksame spezifische Oberfläche aus. Durch regelmäßiges intensives Reinigen wird die aufgebaute Staubschicht entfernt und so zu großen Druckverlusten entgegengewirkt.

Schwierigkeiten können sich bei klebrigen, fetten, agglomerierenden, adhäsiven, abrasiven und hygroskopischen Stäuben ergeben.

#### 4.4.3.7.1 Röhrenfilter

##### Beschreibung

Bei Röhrenfiltern besteht das Filtermedium aus bis zu 5 m langen Röhren mit Durchmessern zwischen 12 und 20 cm. Die Anströmung erfolgt je nach Abreinigungsmethode von innen nach außen oder umgekehrt. Das Gerät enthält einen runden Filter, der aus einer Gruppe vertikaler Röhren besteht, die in einem Zylinder montiert sind. Es sieht einem Zyklon ähnlich und braucht nicht viel Platz. Der Luftstrom wird durch den Filter geleitet und das Feinmaterial lagert sich auf der Oberfläche der einzelnen Röhrenfilter ab. Röhrenfilter werden durch ein vollautomatisches pulsähnliches Umkehrspülsystem gereinigt, das mit Druckluft oder anderen unter Druck stehenden Gasen mithilfe eines mehrstufigen Injektionssystems betrieben wird. Die Röhren werden einzeln gereinigt, sodass die kontinuierliche Reinigung der Röhrenfilter und die kontinuierliche Entstaubung gewährleistet sind.

Das beim Reinigen aus den Röhrenfiltern gelöste Produkt fällt auf die Basis an der Austrittsseite, wo es mittels Luftstrom durch ein besonderes Perforationssystem zum Staubauslass transportiert wird. Die auf diese Weise gereinigten Gase verlassen den Filter durch eine saubere Gaskammer als sauberes Gas.

Die Reinigung der einzelnen Röhrenfilter verringert die Staubmenge, die zu einem gegebenen Zeitpunkt aus dem Filter gelöst wird, wodurch das potenziell explosive Staub-Luft-Volumen in der Filterkammer entsprechend kleiner ist als in herkömmlichen Filtersystemen. CIP-Filter werden in der Nahrungsmittelbranche seit 1995 erfolgreich eingesetzt. Bei Verwendung in der Milchindustrie ist das Filterprodukt mit dem Produkt eines Sprühtrocknungsturms vergleichbar. Röhrenfilter können ohne vorgeschalteten Zyklonabscheider eingesetzt werden.

Das Reinigungssystem für Rundfilter ähnelt dem als CIP-System für Röhrenfilter installierten Reinigungssystem. Ein Luftstrom passiert die CIP-Düsen in der Basis des Röhrenfilters und die übrigen Düsen innerhalb des Filters während des Betriebs, aber nicht während der CIP-Reinigung. So wird eine Verstopfung der CIP-Düsen mit Staub aus der Prozessluft verhindert.

Ein weiterer wichtiger Vorteil besteht darin, dass die Basis des Röhrenfilters in der Zone, in der der Luftstrom mit Staub befrachtet ist, durch die Luftspülung sauber gehalten wird. Dadurch wird die Basis selbst bei sehr hygroskopischen Produkten von massiven Ablagerungen freigehalten. Das ist ein erheblicher Vorteil im Vergleich zu anderen Filterbauarten und verlängert die Betriebsdauer zwischen den Reinigungsphasen. Die Zonen sauberen und verunreinigten Gases, die Röhrenfilter, die Filterwand und die anderen inneren Teile werden über sorgfältig angeordnete Düsengruppen besprüht.

Abbildung 4.27 zeigt einen Röhrenstaubfilter, der in einer großen Molkerei zur Beseitigung von Feinstoffen nach einem Sprühtrockner verwendet wird.

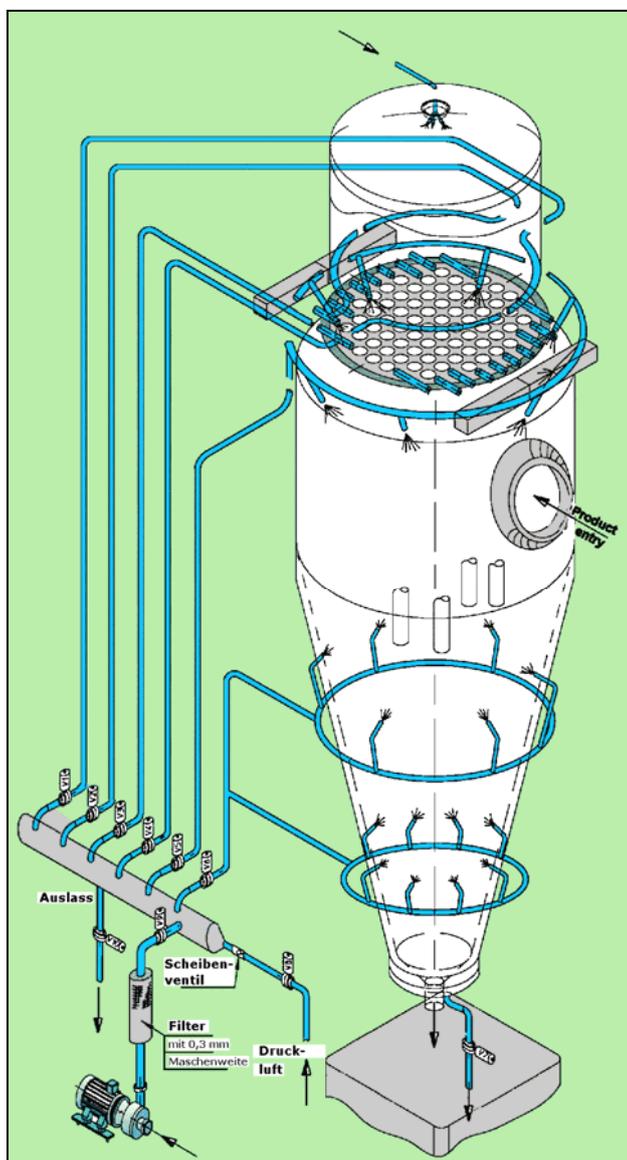


Abbildung 4.27: Röhrenfiltersystem in einer großen Molkerei

### Erreichbare Umweltvorteile

Geringere Staubemissionen in die Luft. Es wird auch ein geringerer Energieverbrauch angegeben (keine Daten).

Weniger Abfallproduktion. Da der Abscheideprozess trocken verläuft, kann es prinzipiell möglich sein, abgechiedenes Material im Prozess oder als Nebenprodukt wiederzuverwenden.

Filter verbrauchen wesentlich weniger Energie als Zyklone und machen weniger Lärm. Wenn für die CIP geeignete Filteranlagen für abgehende Luft verwendet werden, brauchen keine Zyklone eingesetzt zu werden, was erhebliche Energieeinsparungen und Lärmreduktionen ermöglicht. Weniger Wasser- und Reinigungsmittelverbrauch durch CIP-Reinigung.

### Betriebsdaten

Filternde Abscheider können hohe Abscheidegrade erzielen, z. B. > 99 %, wobei selbst sehr feine Partikel sehr effizient abgeschieden werden.

In der in Abschnitt 4.7.5.8 beschriebenen Beispielmolkerei beliefen sich die Staubemissionen durch das Trocknen auf insgesamt 534 kg Staub jährlich nach dem Filtern, was 28 mg Staub pro Tonne getrockneten Produkts entspricht. Angaben zufolge sind Emissionswerte von 10 mg/Nm<sup>3</sup> erzielbar. In derselben Molkerei bestand die Vorgabe, dass zwischen den Reinigungsvorgängen ein Intervall von 3 bis 4 Minuten bestehen solle, um das Abfließen des Wassers aus den Röhren zu ermöglichen. Das vollständige Abfließen ist wichtig, damit es später nicht zum Tropfen an den Düsen kommt. Am Ende des gesamten Reinigungsprogramms müssen die betroffenen Klappen und Ventile in der Rückführleitung offen bleiben, damit das Wasser aus den Röhrenfiltern abfließen kann. Mit dem Trocknen des Systems muss etwa 1 bis 2 Stunden nach dem Ende des Reinigungsvorgangs begonnen werden. Die Röhrenfilter müssen mit warmer Luft getrocknet werden, wobei das Röhrenfilterreinigungssystem ausgeschaltet sein muss, um Betriebsprobleme durch Feuchtigkeit nach dem Neustart zu vermeiden.

### Anwendbarkeit

Röhrenfilter sind in der Nahrungsmittelproduktion weit verbreitet. Sie werden zur Abscheidung von festen und flüssigen Schadstoffen aus der Luft eingesetzt.

### Beispielanlagen

Ein Milchpulverhersteller in Deutschland.

### Referenzliteratur

[9, Verband der Deutschen Milchwirtschaft (German Dairy Association), 1999, 65, Germany, 2002]

## 4.4.3.7.2 Taschenfilter

### Beschreibung

Taschenfilter bestehen aus bis zu 0,5 m hohen, 1,5 m langen und ca. 30 mm dicken Filtertaschen. Die Filterelemente sind mit der offenen Seite zum Reingaskanal hin eingespannt. Die Rohgas-Anströmung erfolgt immer von außen nach innen, in der Regel am oberen Filtertaschenbereich. Tabelle 4.34 zeigt einen Vergleich verschiedener Schlauchfiltersysteme und Abbildung 4.28 zeigt eine industrielle Schlauchfilterkammer.

| Parameter                 | Druckstoßfilter    | Membranglasfaserfilter | Glasfaserfilter    |
|---------------------------|--------------------|------------------------|--------------------|
| Filterverhältnis          | 22 – 25 m/s        | 19 – 25 m/s            | 8 – 10 m/s         |
| Temperaturgrenzwert       | 200 °C             | 280 °C                 | 280 °C             |
| Schlauchtyp               | Polyester          | Membran/Glasfaser      | Glasfaser          |
| Schlauchgröße             | 0,126 x 6,0 m      | 0,292 x 10 m           | 0,292 x 10 m       |
| Gewebefläche pro Schlauch | 2,0 m <sup>2</sup> | 9,0 m <sup>2</sup>     | 9,0 m <sup>2</sup> |
| Käfig                     | Ja                 | Nein                   | Nein               |
| Druckverlust              | 2,0 kPa            | 2,0 kPa                | 2,5 kPa            |
| Schlauchlebensdauer       | Bis zu 30 Monate   | 6 bis 10 Jahre         | 6 bis 10 Jahre     |

Tabelle 4.34: Vergleich verschiedener Schlauchfiltersysteme



**Abbildung 4.28: Foto einer industriellen Schlauchfilterkammer**

#### Erreichbare Umweltvorteile

Geringere Staubemissionen in die Luft. Es wird auch ein geringerer Energieverbrauch angegeben (keine Daten).

Weniger Abfallproduktion. Da der Abscheideprozess trocken verläuft, kann es prinzipiell möglich sein, abgechiedenes Material im Prozess oder als Nebenprodukt wiederzuverwenden.

Filter verbrauchen wesentlich weniger Energie als Zyclone und sind leiser. Wenn für die CIP geeignete Filteranlagen für abgehende Luft verwendet werden, brauchen keine Zyclone eingesetzt zu werden, was erhebliche Energieeinsparungen und Lärmreduktionen ermöglicht. Weniger Wasser- und Reinigungsmittelverbrauch durch CIP-Reinigung.

#### Betriebsdaten

Filternde Abscheider können hohe Abscheidegrade erzielen, z. B. > 99 %, wobei selbst sehr feine Partikel sehr effizient abgeschieden werden. Schlauchfilter können eingesetzt werden, um Staubemissionen auf  $<5 \text{ mg/Nm}^3$  zu senken.

Im Allgemeinen ist der durchschnittliche Abstand zwischen den Fasern erheblich größer als die aufzufangenden Partikel. Die Abscheideraten durch den Siebeffekt werden auch durch Massenkräfte, Hinderniseffekte und elektrostatische Kräfte ergänzt.

#### Anwendbarkeit

Filter werden zur Abscheidung von festen und flüssigen Schadstoffen aus der Luft eingesetzt. Sie werden auch für die Rauchgasreinigung verwendet.

#### Beispielanlagen

Schlauchfilter werden in fast allen Branchen der Nahrungsmittelproduktion verwendet.

#### Referenzliteratur

[65, Germany, 2002]

### **4.4.3.7.3 Schüttschichtfilter**

#### Beschreibung

Das in Schüttschichtfiltern verwendete Filtermedium besteht normalerweise aus einer Kies-, Sand-, Kalkstein- oder Koksschicht mit einer Körnung von 0,3 bis etwa 5 mm. Während der Filtration haften Staubpartikel an der körnigen Schicht an. Eine Staubschicht, die den Abscheideprozess unterstützt, bildet sich an der Oberfläche des

Bettes. Ein Durchbruch des abgeschiedenen Staubs lässt sich durch die Verwendung feiner Partikel ( $< 0,5$  mm) und geringer Strömungsgeschwindigkeiten ( $< 0,1$  m/s) verhindern. Es besteht jedoch das Risiko einer Brückenbildung, die zu niedrigeren Abscheidegrade führt.

Der Füllkörper kann mehrere Meter hoch sein. Die Reinigung erfolgt durch Gegenstromspülung, mechanisches Schütteln in Verbindung mit Spülluft, oder durch bewegliche Düsen während des Reinigens. Die kontinuierliche Reinigung lässt sich durch Verwendung eines Mehrkammerfilters sicherstellen.

### Erreichbare Umweltvorteile

Geringere Staubemissionen in die Luft. Es wird auch ein geringerer Energieverbrauch angegeben (keine Daten).

Filter verbrauchen wesentlich weniger Energie als Zyklone und sind leiser. Wenn für die CIP geeignete Filteranlagen für abgehende Luft verwendet werden, brauchen keine Zyklone eingesetzt zu werden, was erhebliche Energieeinsparungen und Lärmreduktionen ermöglicht. Weniger Wasser- und Reinigungsmittelverbrauch durch CIP-Reinigung.

### Betriebsdaten

Filternde Abscheider können hohe Abscheideraten erzielen, z. B.  $> 99$  %, wobei selbst sehr feine Partikel sehr effizient abgeschieden werden. In Versuchen mit Schütttschichtfiltern sind Reingaswerte von etwa  $10$  mg/Nm<sup>3</sup> für Staub erzielt worden, und zwar bei einem durchschnittlichen Staubgehalt von  $18$  g/Nm<sup>3</sup> im verunreinigten Gas und einer mittleren Partikelgröße von  $0,5$  µm.

Der Abscheidegrad von Schütttschichtfiltern ist nicht so gut wie die von Faserschichtfiltern. Schütttschichtfilter werden daher eingesetzt, um problematische Staubpartikel abzuscheiden oder die Abscheidung bei höheren Abgastemperaturen durchzuführen. Schütttschichtfilter werden häufig in Verbindung mit vorgeschalteten Abscheidern, z. B. mit Zyklonen, eingesetzt.

Im Allgemeinen ist der durchschnittliche Abstand zwischen den Fasern erheblich größer als die aufzufangenden Partikel. Die Abscheidegrade durch den Siebeffekt werden auch durch Massenkräfte, Hinderniseffekte und elektrostatische Kräfte ergänzt.

### Anwendbarkeit

Schütttschichtfilter können eingesetzt werden, um die gleichzeitige Abscheidung von Staub und Gasen zu erreichen. Schütttschichtfilter erfüllen eine unerlässliche Anforderung für die Entstaubung von heißen Gasen, nämlich die Nutzung der thermischen Energie des gereinigten Gasstroms bei hohen Temperaturen. Schütttschichtfilter sind zur Abscheidung von Stäuben geeignet, die die folgenden Eigenschaften bzw. Zustände aufweisen:

- hart und rau
- Temperaturen von bis zu  $1.000$  °C
- vermischt mit chemisch aggressiven Gasen
- brennbar, und wenn ein Funkenbildungsrisiko besteht
- vermischt mit Sprühnebeln
- vermischt mit gasförmigen Schadstoffen wie SO<sub>2</sub>, HCl und HF, wenn durch geeignete Schütttschichten deren gleichzeitige Abscheidung möglich ist.

### Referenzliteratur

[65, Germany, 2002]

#### **4.4.3.8 Absorption**

Die Bezeichnungen „Absorber“ und „Wäscher“ werden manchmal gleichzeitig verwendet, was zu Verwirrung führen kann. Absorber werden im Allgemeinen für die Entfernung von Spurengasen genutzt, und Wäscher für die Beseitigung von Partikeln. Diese Unterscheidung kann nicht immer so strikt getroffen werden, da durch Dampfkondensation oder Nasswäsche Gerüche und gasförmige Substanzen in der Luft auch zusammen mit Staub entfernt werden können (siehe Nassabscheider in Abschnitt 4.4.3.5.3).

Ziel der Absorption ist es, die größtmögliche Flüssigkeitsoberfläche zur Verfügung zu stellen und einen guten Gegenstrom von Gas und Flüssigkeit zu erzeugen. Der Absorptionsprozess nutzt die selektive Löslichkeit der

im Abluftstrom vorhandenen Verunreinigungen im Absorptionsmedium. Es gibt eine Reihe verschiedener Absorberbauarten und viele Unterschiede hinsichtlich der Abscheidungseffizienz bei der Berührung zwischen Gas und Flüssigkeit. Es wird über drei Arten von Absorbern berichtet: Schütttschichtabsorber (siehe Abschnitt 4.4.3.8.1), Prallplattenwäscher (siehe Abschnitt 4.4.3.8.2) und Sprühwäscher (siehe Abschnitt 4.4.3.8.3).

#### Funktionsprinzip

Der Prozess umfasst einen Stoffübergang zwischen einem löslichen Gas und einem flüssigen Lösemittel in einem Gerät, in dem Gas und Flüssigkeit in Kontakt gebracht werden. Die Rate, mit der ein Stoff aus dem Luftstrom entfernt wird, hängt von dessen Sättigungsgrad an der Lösemitteloberfläche innerhalb des Absorbers ab, der wiederum abhängig ist von der Stofflöslichkeit und der Entzugsrate aus dem zirkulierenden Lösemittel durch Reaktion und Ablassen. Dieser Ratenmechanismus bestimmt die Entzugseffizienz für eine Absorptionsanlage mit einer bestimmten Größe bei einem bestimmten Luftvolumenstrom. Deshalb hängt die Entzugseffizienz von der Reaktionszeit, dem Sättigungsgrad an der Flüssigkeitsoberfläche und der Reaktivität der Gasbestandteile innerhalb der absorbierenden Lösung ab.

Vorausgesetzt, dass die zu entziehenden luftgetragenen Substanzen in angemessenem Maße wasserlöslich sind, kann der Absorber so geplant werden, dass eine bestimmte gewünschte Entzugseffizienz erreicht wird. Das Problem besteht in der Notwendigkeit, die Konzentration an der Oberfläche der absorbierenden Flüssigkeit so gering zu halten, dass die treibende Kraft für das In-Lösung-Gehen erhalten bleibt. Deshalb wird oft zur Erzielung einer angemessenen Effizienz zuviel Wasser benötigt. Daher ist es im Allgemeinen nicht praktikabel, verschiedene Substanzen mit Wasser allein zu entziehen, sodass üblicherweise andere Absorptionsmittel genutzt werden.

Systeme, die nur mit Wasser arbeiten, kommen jedoch als erste Stufe vor anderen Absorbern in Frage, aber ihre Effektivität hängt zum großen Teil von anderen Mechanismen als von der Absorption ab. Beispielsweise führt die Wasserabsorption eines nicht gesättigten Luftstroms durch einen adiabatischen Kühlvorgang zur Abkühlung des Luftstroms bis zur Sättigung. Dieser Kühleffekt kann zur Kondensation und dem Entzug der Substanzen aus dem Luftstrom führen, wenn sie auf eine Temperatur unterhalb ihres Siedepunkts abkühlen.

#### Erwägungen zu Planung und Bauart

Bei allen Bautypen von Absorbern stellt die effektive Verteilung von Flüssigkeit und Gas eine grundlegende Notwendigkeit dar. Um einen Absorber gemäß den Grundsätzen der chemischen Verfahrenstechnik optimal zu planen, sind Angaben zu Konzentration, Löslichkeit und Stoffübergang für die Substanzen, die dem Gasstrom entzogen werden sollen, erforderlich. Die meisten Luftemissionen in der Nahrungsmittelproduktion stellen komplexe Gemische dar, bei denen es schwierig ist, sämtliche beteiligten chemischen Substanzen zu bestimmen, und noch schwieriger, deren Konzentrationen zu ermitteln. Die Art und Kinetik der Oxidationsreaktionen sind im Allgemeinen nicht bekannt und selbst für einzelne Verbindungen nur schwer zu bestimmen. Es wird behauptet, dass Planung und Konstruktion von Absorptionsanlagen eher auf empirischer als auf wissenschaftlicher Grundlage erfolgen muss. Daher wird das Schütttschichtvolumen anhand desjenigen Volumens gewählt, von dem man zuvor gesehen hat, dass es für die einigermaßen vollständige Absorption der absorbierbaren Substanzen geeignet ist. Wenn nur wenig Betriebserfahrungen mit dem betreffenden Ausstoß zur Verfügung stehen, können Pilotversuche unternommen werden.

Pilotanlagenversuche oder bereits vorhandene Erfahrung können also zur Bestimmung der Höhe des Füllkörpers eingesetzt werden, die zum Erreichen einer bestimmten Leistung erforderlich ist. Der Füllkörper wird so gewählt, dass die für die erforderliche Effizienz benötigte Einheitenhöhe erreicht werden kann. Größe und Art des Schüttmaterials, die lineare Gasgeschwindigkeit, die den Absorberdurchmesser bestimmt, die lineare Flüssigkeitgeschwindigkeit, der Gasdruckverlust und die Absorbereffizienz pro Einheitenhöhe, die die gepackte Höhe bestimmt, stehen alle in einem Zusammenhang. Deshalb wird bei der Planung auf die Optimierung von Investitions- und Betriebskosten geachtet; dabei sind der erforderliche volumetrische Durchsatz, die Absorptionseffizienz und Einschränkungen wie das mögliche Verstopfen des Füllkörpers und der maximal zulässige Druckverlust zu berücksichtigen.

Typische Bereiche für die oben genannten Parameter sind in Tabelle 4.35 angegeben.

| Planungsparameter        | Einheit                   | Werte           |
|--------------------------|---------------------------|-----------------|
| Gasgeschwindigkeit       | m/s                       | 0,5 – 2,0       |
| Gasvolumenstrom          | kg/m <sup>2</sup> /Stunde | 2.500 – 5.000   |
| Flüssigkeitsvolumenstrom | kg/m <sup>2</sup> /Stunde | 25.000 – 50.000 |
| Gasverweildauer          | Sekunde                   | 1 – 3           |
| Druckverlust             | mm/Meter                  | 20 – 50         |
| Flüssigkeitsablassrate   | % des Rückführungsstroms  | 0 – 10          |
| Flutung                  | % der Flutung             | 40 – 60         |

Tabelle 4.35: Typische Richtwerte für die Absorberplanung

### Absorptionsreagenzien

Die Absorptionseffizienz lässt sich steigern, wenn die Absorptionsflüssigkeit ein Reagenz enthält, das mit den im Luftstrom enthaltenen Substanzen reagiert. Dadurch wird die Konzentration der luftgetragenen Substanzen an der Flüssigkeitsoberfläche effektiv reduziert und so die Absorptionstriebkraft aufrechterhalten, ohne dass riesige Mengen Absorptionsflüssigkeit verbraucht werden. Es gibt eine Anzahl spezifischer Reagenzien, die innerhalb von Absorptionssystemen eingesetzt werden können, um übelriechende und andere organische Komponenten aus einem Luftstrom zu entfernen. Dabei handelt es sich im Allgemeinen um oxidierende Lösungen.

Die am häufigsten verwendeten Reagenzien sind unter anderem Natriumhypochlorit, Wasserstoffperoxid, Ozon und Kaliumpermanganat. Die Verwendung von Säuren und Laugen als Absorptionsmedien ist ebenfalls recht weit verbreitet, und oft wird das Säure-/Lauge-System in Verbindung mit einem oxidierenden Absorptionsmittel eingesetzt. Aufgrund der erheblichen Zahl von Substanzen, die in den Luftemissionen einer Nahrungsmittelproduktionsanlage vorhanden sein können, werden oft mehrstufige Absorber eingesetzt. Ein Absorbersystem könnte also aus einem vorgeschalteten Wasserwäscher bestehen, an den sich eine saure oder basische und schließlich eine oxidierende Stufe anschließen.

Natriumhypochlorit ist ein weit verbreitetes Oxidationsmittel, was in erster Linie auf seine hohe Reaktivität zurückzuführen ist. Hypochlorit hat sich als besonders nützlich in Anlagen erwiesen, deren Emissionen erhebliche Konzentrationen an übelriechenden Schwefel- und Stickstoffverbindungen enthalten.

Hypochlorit wird generell bei basischem pH eingesetzt, um die Dissoziation in freies Chlor zu vermeiden. Es besteht eine gewisse Tendenz für eine Reaktion des Hypochlorits mit bestimmten Verbindungen über eine Chlorierungsreaktion anstelle einer Oxidationsreaktion. Das ist insbesondere dann zu befürchten, wenn ein Luftstrom aromatische Substanzen enthält, aus denen chlorierte aromatische Verbindungen im behandelten Gasstrom entstehen könnten. Bei höheren Hypochloritkonzentrationen ist das Chlorierungspotenzial höher, sodass sich das Risiko verringern lässt, wenn in der Absorptionsflüssigkeit geringere Hypochloritkonzentrationen vorgesehen werden, als für eine optimale Absorption tatsächlich erforderlich wären.

Um eine Lösung für dieses Problem zu finden, wurde ein Prozess entwickelt, der im Wesentlichen einem herkömmlichen Hypochloritabsorber gleicht, aber über einen in das System für die Wiederverwendung der Flüssigkeit integrierten Katalysator verfügt. Der Katalysator basiert auf Nickeloxid und das System soll die Hypochloritreaktionsrate drastisch steigern und sämtliche Chlorierungsreaktionen unterbinden. Die potenziellen Chlorierungsreaktionen werden vermieden, weil der Katalysator den Abbau des Hypochlorits in gasförmigen Sauerstoff und Natriumchlorid fördert, und nicht den Zerfall unter Freisetzung freien Chlors. Dadurch wiederum können höhere Hypochloritkonzentrationen im Absorber eingesetzt werden, was zu einer verbesserten Effizienz führt. Der pH-Wert wird auf etwa pH 9 eingestellt, und das Redoxpotenzial wird zur Erzielung einer optimalen Spannung reguliert.

Wasserstoffperoxid ist im Allgemeinen weniger effektiv als Hypochlorit, weil es über weniger Oxidationskraft verfügt. Es hat jedoch den Vorteil, dass sein Reaktionsprodukt Wasser ist und es in Anwendungen eingesetzt werden kann, in denen Aromaten auftreten (Begründung siehe oben). Wasserstoffperoxid wird allgemein unter angesäuerten Bedingungen verwendet, die in erster Linie zur Regulierung seiner Zersetzung dienen.

Ozon ist ein starkes Oxidationsmittel, wobei seine Oxidationskraft in der flüssigen Phase größer ist als in der Gasphase. Eine neue Anwendung, bei der ultraviolettes Licht eingesetzt wird, um die oxidative Leistung von Ozon zu verstärken, wird in Abschnitt 6.1 ausführlicher besprochen.

In den vergangenen Jahren wurde eine Reihe von Absorptionslösungen verwendet, die auf oberflächenaktiven Substanzen basieren, aber es gibt nur eingeschränkte Informationen zu deren Leistung. Insbesondere wurde ein System erfolgreich eingesetzt, das auf einem nicht-ionischen oberflächenaktiven Stoff beruht und schaumreduziert ist, wie die Materialien, die bei Spülmitteln für Geschirrspüler verwendet werden.

Es werden auch feste Oxidationsmittel verwendet, z. B. in einem Kalziumoxidwäscher, in dem Kalziumoxidpartikel mit dem übelriechenden Gasstrom in Berührung gebracht werden und einen festen Kalziumkarbonatrückstand bilden. Diesbezüglich wird aber über eine begrenzte Leistung bei der Geruchseseitigung sowie schwerwiegende Betriebsprobleme beim Umgang mit den Feststoffen berichtet. Der Einsatz ausschließlich flüssiger Absorptionsmittel ist daher gebräuchlicher.

#### 4.4.3.8.1 Schüttschichtabsorber

##### Beschreibung

Schüttschichtabsorbersysteme stellen den am häufigsten verwendeten Absorbentyp dar und bieten die Vorteile einer maximierten Oberfläche pro Volumeneinheit und eines relativ geringen Druckverlusts. Abbildung 4.29 zeigt den Plan eines Schüttschichtabsorbers.

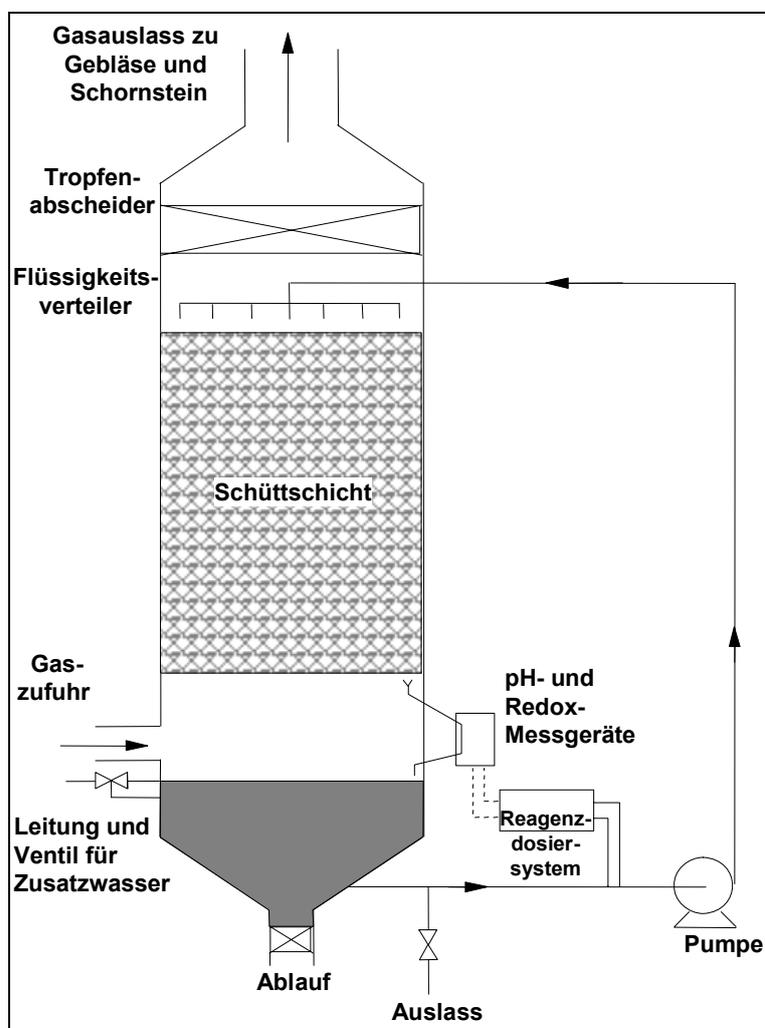


Abbildung 4.29: Plan eines Schüttschichtabsorbers

Der zu behandelnde Luftstrom wird als Gegenstrom durch den umlaufenden Flüssigkeitsstrom geleitet. Der Schüttschichtbereich besteht aus einer großen Zahl von Schüttstücken, die üblicherweise aus Kunststoff

hergestellt werden und eine beträchtliche Oberfläche bieten, an der Gas und Flüssigkeit miteinander in Kontakt kommen können. Das Flüssigkeitssystem kann von einer einfachen Umwälzpumpe bis hin zu einer aufwendigen Dosierstation für die Zugabe von Chemikalien in Verbindung mit pH-gesteuerten Dosier- und Regelungsvorrichtungen reichen. Die beste Flüssigkeitsverteilung lässt sich angabegemäß mit einer Reihe von Düsen erzielen, die symmetrisch oberhalb der Schüttelschicht angeordnet sind. Der behandelte Luftstrom wird durch einen Tropfenabscheider abgegeben, damit vor dem Austritt eventuell mitgeschleppte Tröpfchen entfernt werden.

### Erreichbare Umweltvorteile

Beseitigung von Gerüchen, Gasen und Staub aus der Luft.

### Medienübergreifende Auswirkungen

Es fällt Abwasser an. Am Rauchgasauslass ist wahrscheinlich eine Rauchfahne sichtbar.

### Betriebsdaten

Absorber sind den Angaben zufolge bei der Beseitigung bestimmter Bestandteile effektiver als bei der Beseitigung allgemein, und ihre Effizienz liegt normalerweise zwischen 70 und 80 %.

Die Verteilung der Flüssigkeit über eine zentrale Düse wird immer seltener angewandt, da die damit zu erzielende Verteilung nicht so gut ist. Je nach vertikaler Länge des Füllkörpers innerhalb des Absorbers kann es erforderlich sein, weitere Systeme zur Flüssigkeitsverteilung einzubauen.

Die Geräte sind kompakt, sodass Absorber selbst nicht viel Platz erfordern. Es kann jedoch Platz für die sichere Lagerung von Chemikalien erforderlich sein.

### Anwendbarkeit

Absorber sind allgemein für eine große Bandbreite volumetrischer Luftströme geeignet, die Gase und/oder Gerüche in relativ geringen Konzentrationen enthalten.

### Wirtschaftliche Aspekte

Im Vergleich zu anderen nachgeschalteten Techniken zur Geruchsminderung relativ kostengünstig. Relativ geringe Investitions- und Betriebskosten. Ihre Kosteneffektivität wird gemindert, wenn das zu behandelnde Abgas einen hohen Feuchtigkeitsgehalt hat, da es Wasserdampf selektiv absorbiert.

### Beispielanlagen

Zur Geruchsminderung weit verbreitet.

### Referenzliteratur

[34, Willey A R and Williams D A, 2001]

#### **4.4.3.8.2 Prallplattenwäscher**

### Beschreibung

Prallplattenwäscher bestehen aus einem senkrechten Turm, in dem mehrere waagerechte durchlöchernte Bleche oder Siebplatten übereinander angeordnet sind. In geringer Entfernung über den Öffnungen der Platten befinden sich Prallbleche. Die Waschflüssigkeit wird oben in den Turm eingefüllt und durchfließt dann nacheinander alle Bleche. Die zu behandelnde Luft tritt am Boden in den Turm ein und strömt nach oben, wobei sie die Löcher in den Platten passiert. Die Geschwindigkeit des Luftstroms reicht dabei aus, um ein Durchsickern der Flüssigkeit durch die Löcher zu verhindern. Der zu behandelnde Luftstrom wird durch die von den Blechen überlaufenden Flüssigkeitsströme geleitet. Es gibt viele Variationen hinsichtlich der Form der Bleche und der Anordnung der Düsen für die Flüssigkeit. Abbildung 4.30 zeigt einen Prallplattenwäscher.

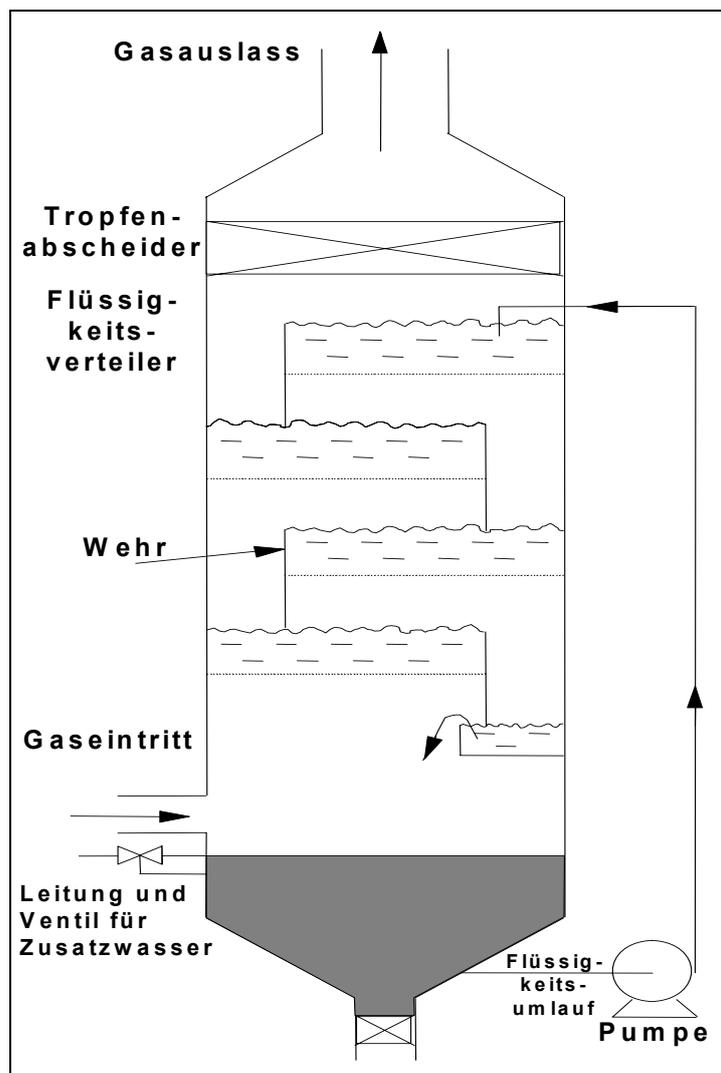


Abbildung 4.30: Schema eines Prallplattenwäschers

#### Erreichbare Umweltvorteile

Beseitigung von Gerüchen, gasförmigen Substanzen und Staub aus der Luft.

#### Medienübergreifende Auswirkungen

Es fällt Abwasser an. Am Rauchgasauslass ist wahrscheinlich eine Rauchfahne sichtbar.

#### Betriebsdaten

Absorber zeichnen sich im Allgemeinen den Angaben zufolge durch einen relativ geringen Druckverlust aus. Sie sind den Angaben zufolge bei der Beseitigung bestimmter Bestandteile effektiver als bei der Beseitigung allgemein, und ihre Effizienz liegt normalerweise zwischen 70 und 80 %.

Die Geräte sind kompakt, sodass Absorber selbst nicht viel Platz erfordern. Es kann jedoch Platz für die sichere Lagerung von Chemikalien erforderlich sein.

#### Anwendbarkeit

Absorber sind allgemein für eine große Bandbreite volumetrischer Luftströme geeignet, die Gase und/oder Gerüche in relativ geringen Konzentrationen enthalten.

#### Wirtschaftliche Aspekte

Im Vergleich zu anderen nachsorgenden Techniken zur Geruchsminderung relativ kostengünstig. Relativ geringe Investitions- und Betriebskosten. Ihre Kosteneffektivität wird gemindert, wenn das zu behandelnde Abgas einen hohen Feuchtigkeitsgehalt hat, da es Wasserdampf selektiv absorbiert.

### Beispielanlagen

Wird in der Nahrungsmittelproduktion eingesetzt.

### Referenzliteratur

[34, Willey A R and Williams D A, 2001]

#### 4.4.3.8.3 Sprühwäscher

##### Beschreibung

Ein Sprühwäscher umfasst einfach einen Flüssigkeits-Sprühstrahl, der in einem Gefäß mit einem aufwärts gerichteten Luftstrom in Berührung kommt. Das Gefäß enthält keinen Füllkörper oder Platten oder sonstigen Vorrichtungen zur Intensivierung des Kontakts zwischen Gas und Flüssigkeit. Eine typische Sprühturm-konfiguration ist in Abbildung 4.31 dargestellt.

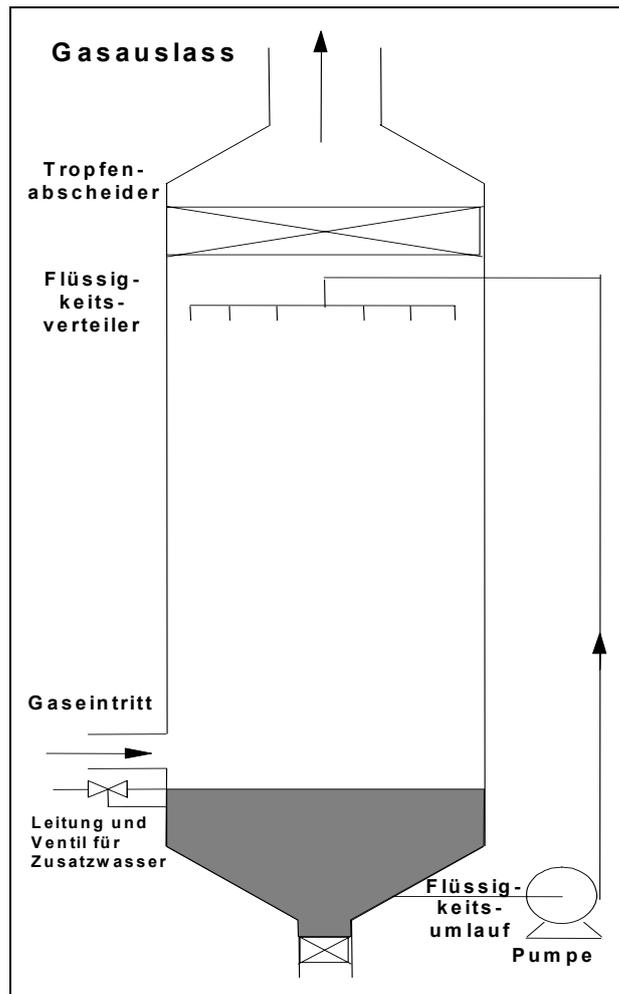


Abbildung 4.31: Schema einer Sprühkammer

##### Erreichbare Umweltvorteile

Entfernung von kondensierbaren Dämpfen und Staub aus der Luft.

##### Medienübergreifende Auswirkungen

Es fällt Abwasser an. Am Rauchgasauslass ist wahrscheinlich eine Rauchfahne sichtbar.

##### Betriebsdaten

Die Geräte sind kompakt, sodass sie selbst nicht viel Platz erfordern. Es kann jedoch Platz für die sichere Lagerung von Chemikalien erforderlich sein.

Wenn vorhandener Staub oder kondensierbare Stoffe ein potenzielles Problem darstellen und in demselben Gerät gasförmige Schadstoffe oder Gerüche beseitigt werden sollen, kann es zu erheblichen Betriebsproblemen

und Ausfallzeiten während der Reinigung und erneuten Inbetriebnahme des Absorbers kommen. In dieser Hinsicht kann es sinnvoll sein, einen Wellenprallplattenwäscher zu installieren<sup>14</sup>. Darin wird der in das Gerät eintretende Luftstrom durch eine Reihe von wellenförmigen Platten geleitet, vor denen sich jeweils eine Sprühvorrichtung für die Flüssigkeit befindet. Die Wellenplattenkonstruktion kann so konstruiert werden, dass sie *in situ* entfernt, gereinigt und wieder in das Gerät eingesetzt werden kann, ohne dass die Anlage abgeschaltet werden muss.

#### Anwendbarkeit

Eine Sprühkammer ist im Allgemeinen nicht zur Beseitigung von Gerüchen oder gasförmigen Substanzen geeignet, da der Stoffübergang begrenzt ist. Wenn der zu behandelnde Luftstrom jedoch viel Staub oder kondensierbares Material enthält, so können diese vor einer Behandlung mit intensiverem Gas-Flüssigkeitskontakt, wie z. B. in einem Prallplattenwäscher oder Schütttschichtabsorber, mit einem einfachen Sprühturm entfernt werden.

#### Wirtschaftliche Aspekte

Relativ geringe Investitions- und Betriebskosten.

#### Referenzliteratur

[34, Willey A R and Williams D A, 2001]

### 4.4.3.9 Aktivkohlebehandlung (Adsorption)

#### Beschreibung

Die Adsorption stellt ein Grundverfahren da, bei der luftgetragene Komponenten an einer fein gekörnten aktiven Oberfläche haftenbleiben. Es gibt eine Reihe nutzbarer Aktivstoffe, die für allgemeine Anwendungen genutzt werden. Dazu zählen Zeolite, Quarze, Polymerharze und Aktivkohle. In der Nahrungsmittelproduktion ist Aktivkohle derzeit das am häufigsten eingesetzte Absorptionsmittel, weshalb allgemein von Aktivkohlebehandlung gesprochen wird.

Die Adsorption an Kohlenstoff ist ein dynamischer Prozess, bei dem Dampfmoleküle auf die Oberfläche des Feststoffs auftreffen und dort eine Zeit verweilen, bevor sie wieder in die Dampfphase desorbieren. Zwischen Adsorption und Desorption stellt sich ein Gleichgewicht ein. Das bedeutet, dass eine bestimmte Konzentration einer Verbindung auf der Kohlenstoffoberfläche einer Konzentration oder einem Teildruck dieser Verbindung in der Gasphase entspricht.

Der Adsorptionsprozess kann entweder physikalischer Natur sein, wenn die adsorbierten Moleküle durch Van-der-Waals-Kräfte an der Oberfläche gehalten werden, oder chemischer Natur, wenn zwischen adsorbierten Molekülen und der Oberfläche eine chemische Brückenbildung erfolgt. Bei beiden Prozessen wird Wärme freigesetzt, beim letztgenannten mehr als beim ersten.

Aktivkohle kann aus einer Reihe kohlenstoffhaltiger Materialien hergestellt werden, darunter Holz, Kohle, Torf, Nussschalen, Braunkohle, Knochen und Petroleumrückstände. In Dampfphasenanwendungen werden üblicherweise Produkte auf Muschelkalk- und Kohlebasis verwendet. Der Herstellungsprozess besteht aus der Dehydrierung und Karbonierung des Rohmaterials, wodurch flüchtige Materie ausgetrieben und eine rudimentäre Porenstruktur erzeugt wird. Anschließend folgt die thermische oder chemische Aktivierung.

Aktivkohle, die bei der Geruchsminderung zum Einsatz kommt, hat die typischen in Tabelle 4.36 angegebenen Eigenschaften.

| Parameter     | Einheit            | Eigenschaft |
|---------------|--------------------|-------------|
| Partikelgröße | mm                 | 1,4 – 2,0   |
| Schüttdichte  | kg/m <sup>3</sup>  | 400 – 500   |
| Oberfläche    | m <sup>2</sup> /g  | 750 – 1.500 |
| Porenvolumen  | cm <sup>3</sup> /g | 0,8 – 1,2   |

**Tabelle 4.36: Eigenschaften von Aktivkohle**

<sup>14</sup> Anm. d. UBA-Bearb.: (... , um vor allem Tropfen abzuscheiden)

Kohlebetten können entweder einmal verwendet und entsorgt oder regeneriert werden. Regenerative Systeme kommen üblicherweise in Anlagen zum Einsatz, in denen die Rückgewinnung des aufgefangenen Materials wirtschaftlich attraktiv ist. Häufiger sind Adsorbersysteme mit festem Bett für den Einmalgebrauch. Regenerative Systeme werden üblicherweise mit Mehrfach-Kohlebetten konzipiert, sodass Adsorption und Desorption gleichzeitig erfolgen können. Es ist meistens nötig, die Temperatur der Adsorbenschicht zu erhöhen, um das Adsorbat freizusetzen, meist mit Hilfe von Dampf. Ein regeneratives System erfordert daher einen zusätzlichen Auffangmechanismus für Material, das im regenerativen Prozess desorbiert wird.

Das Festschichtsystem besteht aus einer Schicht Aktivkohle, durch die der zu behandelnde Gasstrom geführt wird. Die Kohle liegt entweder als einfach gepackte Schicht oder in Form von Kohlefiltern vor. Die Filter sind im Wesentlichen mit pulverförmiger Aktivkohle gefüllte Papier- oder Pappkartuschen. Im Allgemeinen wird die Kartuschenversion für eine allgemeine Raumbelüftung eingesetzt, wogegen das Schüttschichtsystem zur Geruchsminderung in Prozessabluft verwendet wird. Wenn die Aktivkohle verbraucht ist, was sich beispielsweise durch eine erhöhte Geruchskonzentration im Auslass bemerkbar macht, müssen die Kohle oder die Kartuschen ausgetauscht werden. Das Schüttschichtsystem hat den Vorteil, dass es in den meisten Fällen zur Regeneration an den Lieferanten zurückgegeben werden kann, während die Kartuschenfilter in der Regel durch den Benutzer entsorgt werden müssen.

Die Planungsgrundlage für die Raumbelüftung mit Kartuschenfiltern ist eine ganz andere als für die Prozessgeruchsminderung mit Schüttschichten. Im Allgemeinen werden Kartuschenfilter bei kleinen Abluftströmen eingesetzt, die mit Unterbrechungen oder nur selten auftreten und eine geringe Konzentration an Sorbentien aufweisen. Umgekehrt wird das Schüttschichtsystem verwendet, wenn die Konzentration der Substanzen im zu behandelnden Luftstrom wesentlich höher als in der normalen Raum- oder Fabrikluft ist. Der Hauptunterschied zwischen den Planungsgrundlagen der einzelnen Systeme ist die Verweildauer; bei der Raumbelüftung sind nur 0,1 bis 0,2 Sekunden erforderlich, bei der Behandlung von Prozessabluft hingegen zwischen 1 und 3 Sekunden. Die Wahl der Verweildauer stellt im Wesentlichen einen Kompromiss zwischen dem physischen Schichtvolumen und der Zeit bis zu dessen Ersatz dar.

In Tabelle 4.37 sind die Funktionsprinzipien der drei wichtigsten Adsorbertypen angegeben.

| Adsorber                                      | Funktionsprinzip  |
|---|---|
| Instationär betriebener Festbettadsorber      | Das kontaminierte Gas wird durch eine stationäre Adsorbenschicht geleitet                   |
| Wirbelschichtbettadsorber                     | Das kontaminierte Gas wird durch eine Suspension des Adsorptionsmittels geleitet.           |
| Kontinuierlich betriebener Wanderbettadsorber | Das Adsorptionsmittel fällt der Schwerkraft folgend durch den aufwärts gerichteten Gasstrom |

**Tabelle 4.37: Funktionsprinzipien der wichtigsten Adsorbertypen**

Erreichbare Umweltvorteile

Beseitigung von Gerüchen, Gasen und Staub aus der Luft.

Medienübergreifende Auswirkungen

Energieverbrauch. Es entsteht Abfall, z. B. wenn die Aktivkohle entsorgt werden muss.

Betriebsdaten

Die Installation eines Kohlenstoffadsorptionssystems ist recht einfach, da es nur aus einem Gebläse und einem Gefäß für das Kohlebett besteht. Mit der Kohlenstoffadsorption lassen sich Geruchsbeseitigungseffizienzen von 80 - 99 % erreichen.

Die absorptive Kapazität der Aktivkohle wird als Gewichtsprozent angegeben und bezeichnet die Menge des betreffenden Materials, die pro Masseneinheit Kohlenstoff adsorbiert werden kann. Diese Zahlen schwanken erheblich von Tiefstwerten von Null bis zu Höchstwerten von 110 % und sind für übelriechende Abgase, die potenziell eine Vielzahl einzelner Substanzen enthalten, eher bedeutungslos. In diesem Sinn können für die Schätzung der zu erwartenden Lebensdauer eines Kohlebetts in der Nahrungsmittelproduktion 30 % als allgemeiner Richtwert angenommen werden.

Die zu erwartende Lebensdauer des Kohlebets kann dann anhand der geplanten Verweildauer, der organischen Fracht und des zu behandelnden Luftstroms abgeschätzt werden. Das folgende Beispiel veranschaulicht die Vorgehensweise. Zuerst wird die organische Fracht anhand der folgenden Gleichung berechnet:

$$\text{Fracht} = \text{Luftstrom} \times \text{Konzentration}$$

Unter Annahme eines Luftstroms von 10.000 m<sup>3</sup>/h mit einer organischen Stoffkonzentration von 50 mg Kohlenstoff/m<sup>3</sup> und einem Kohlebett mit einer vorgesehenen Verweildauer von 1 Sekunde beträgt die organische Fracht 0,5 kg/h. Eine Verweildauer von 1 Sekunde erfordert ein Kohlebettvolumen von 2,78 m<sup>3</sup>. Ausgehend von einer Schüttdichte der Aktivkohle von 500 kg/m<sup>3</sup> wäre die Kohle in der Lage, 30 % von 1.390 kg zu adsorbieren, was 2.780 Betriebsstunden entspricht. Das Bett müsste also ungefähr dreimal jährlich ersetzt werden.

#### Anwendbarkeit

Die Aktivkohlebehandlung ist generell für geringe Luftdurchsatzraten von weniger als 10.000 m<sup>3</sup>/h geeignet, sowie auch dann, wenn der zu entfernende Schadstoff eine niedrige Konzentration von z. B. unterhalb 50 mg/Nm<sup>3</sup> hat. Hinsichtlich der Geruchsminderung liegen die Hauptanwendungen der Aktivkohlebehandlung in der Reinigung von Raumabluft und der Behandlung übelriechender Prozessemissionen.

Wenn im zu behandelnden Gasstrom Staub vorhanden ist, kann dieser die Effizienz des Kohlebets stark stören und auch den Druckverlust während des Betriebs vergrößern. Die Aktivkohlebehandlung kann daher nicht eingesetzt werden, wenn Staub oder auch nur kondensierbares Material vorhanden sind. Staub und kondensierbare Stoffe können durch einen Vorfilter entfernt werden, was die Anlage jedoch komplizierter und teurer macht und zusätzliche verfahrensbedingte Probleme bei den Reinigungsanforderungen und bei Staubdurchbrüchen hervorruft.

Allgemein gilt: Je niedriger die Temperatur, desto größer die adsorbierte Menge und folglich desto länger die Durchbruchzeit bzw. die Lebensdauer des Bettes. Als Richtwert gilt, dass die Aktivkohlebehandlung bei Temperaturen über 40 °C nicht anwendbar ist. Des Weiteren wird die Effizienz der Aktivkohle bei einer relativen Luftfeuchtigkeit von mehr als 75 % gemindert, außer bei wasserlöslichen Verbindungen wie den geringerwertigen Aminen und Schwefelwasserstoff. Die selektive Adsorption von Wasser kann zu einer Kondensation innerhalb des Bettes führen, wodurch die Kohle inaktiv wird. Das Bett müsste dann vor der erneuten Verwendung erst austrocknen.

#### Wirtschaftliche Aspekte

Die Investitionskosten für die Technik sind relativ gering. Die Betriebskosten sind hoch, da z. B. die Aktivkohle etwa 2.400 EUR/t kostet. Eine Regeneration ist normalerweise nicht wirtschaftlich lohnend, sodass das Kohlebett vollständig erneuert werden muss, wenn seine Adsorptionseffizienz zu sinken beginnt. Je nach Geruchsemissionsrate und Geruchsstoffkonzentration kann das bereits nach kurzer Zeit der Fall sein.

#### Referenzliteratur

[34, Willey A R and Williams D A, 2001]

#### **4.4.3.10 Biologische Behandlung**

Der Einsatz von Mikroorganismen für den Abbau von luftgetragenen Geruchsemissionen ist weit verbreitet. Die Reaktionsgeschwindigkeit ist beim biologischen Abbau relativ gering, und die Optimierung der Betriebsbedingungen kann entscheidenden Einfluss darauf haben.

Es gibt zwei Arten der biologischen Behandlung, die Biofilter (siehe Abschnitt 4.4.3.10.1) und die Biowäscher (siehe Abschnitt 4.4.3.10.1). Am beliebtesten sind die Biofilter.

Es gibt eine Reihe von Faktoren, die bei der Planung berücksichtigt werden müssen, damit ein effektiven Betrieb gewährleistet ist: Verweildauer, Temperatur, Feuchtigkeit, Auswirkungen von Staub und Fett auf den Filter, Befrachtung mit organischen/riechenden Stoffen sowie Beschaffenheit und Eigenschaften des Filtermaterials.

In Tabelle 4.38 sind Vor- und Nachteile biologischer Behandlungsverfahren angegeben.

| Vorteile                                       | Nachteile   |
|--|---|
| Relativ geringe Investitionskosten             | Auf Feuchtlufttemperaturen von <40 °C beschränkt. |
| Relativ geringe Betriebskosten                 | Großer Platzbedarf (Bodenfläche)                  |
| Potenziell hohe Geruchsbeseitigung ~ 90 – 99 % | Potenzielle Rauchfahnenbildung                    |
| Einfach in Konstruktion und Betrieb            | pH und Wassergehalt müssen geregelt werden.       |
|  | Langsame Anpassung an Konzentrationsschwankungen  |

**Tabelle 4.38: Vor- und Nachteile der biologischen Behandlung**  
 [34, Willey A R and Williams D A, 2001]

Funktionsprinzip

Der Biofilm ist die Mikroorganismen enthaltende Wasserschicht, von der die einzelnen Partikel des Filtermaterials umgeben sind. Wenn der zu behandelnde Luftstrom die Teilchen umfließt, ergibt sich ein kontinuierlicher Stoffübergang zwischen Gasphase und Bioschicht. Im Abgas vorhandene flüchtige Substanzen werden zusammen mit Sauerstoff teilweise in der flüssigen Phase der Bioschicht gelöst. Der zweite Reaktionsschritt besteht im aeroben biologischen Abbau der Substanzen in der flüssigen Phase. Auf diese Weise wird ein Konzentrationsgradient in der Bioschicht erzeugt, der einen kontinuierlichen Stofffluss der Substanzen aus dem Gas in die nasse Bioschicht aufrechterhält.

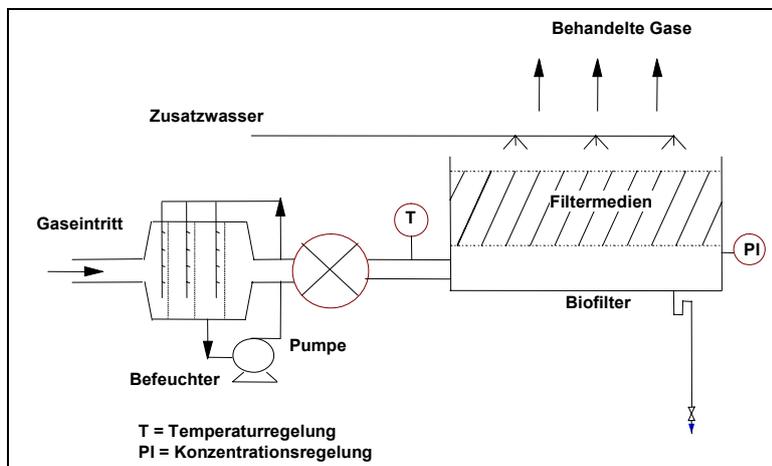
Der Transport über die Phasengrenze und die Diffusion in die Bioschicht liefern den in der Bioschicht lebenden Mikroorganismen Nahrung. Für das Zellwachstum erforderliche Nährstoffe stammen aus dem Filtermaterial.

**4.4.3.10.1 Biofilter**

Beschreibung

In Biofiltern werden die Schadstoffe vom Filtermaterial absorbiert und von den auf einem festen Filtermedium befindlichen Mikroorganismen abgebaut. Das Filtermaterial ist als Füllkörper angeordnet und wird von den Abgasen durchdrungen. Abgase, die hohe Staubkonzentrationen enthalten, müssen erst einer Staubentfernung unterzogen werden, bevor sie in den Biofilter geleitet werden können.

Biofilter können entweder mit abwärts- oder mit aufwärtsgerichteter Strömung betrieben werden. Die relativen Vorzüge der zwei Methoden sind ungewiss, und wahrscheinlich ist die Verfahrenseffizienz in beiden Fällen gleich. Der Druckverlust an Biofiltern ist gering und liegt üblicherweise im Bereich von 10 bis 25 mm/m Füllkörperhöhe. Dieser geringe Druckverlust lässt erkennen, dass die sachgerechte Planung der Luftverteilung sowohl in Anlagen mit abwärtsgerichteter als auch in Anlagen mit aufwärtsgerichteter Strömung von großer Bedeutung ist. Ein typisches Schema für einen Biofilter ist in Abbildung 4.32 dargestellt.



**Abbildung 4.32: Schema eines Biofilters**

Das zu behandelnde Abgas wird zunächst in einen Befeuchter geleitet, wo es im Gegenstrom mit rezirkulierendem Wasser in Berührung gebracht wird. Die Luft, die den Befeuchter verlässt, wird anschließend zum Biofilter geleitet.

Es ist nicht übliche Praxis, den Befeuchter mit einer kontinuierlichen Zufuhr von Zusatzwasser zu betreiben, da ansonsten eine Abwasserabgabe erforderlich würde.

Die regelmäßige Bewässerung der Oberseite des Füllkörpers ermöglicht die Beibehaltung des erforderlichen Feuchtigkeitsgehalts im Filtermaterial von 40 - 60 %. Sämtliches Wasser, das den Füllkörper durchläuft, sei es durch Bewässerung oder Regen, kann zum Befeuchter zurückgeführt werden, damit kein Abwasser aus dem System abgegeben wird.

Es gibt eine Vielzahl von Filtermaterialien, die in Biofiltern verwendet werden. Die wichtigsten Eigenschaften, die das Filtermaterial haben muss, sind eine große spezifische Oberfläche, z. B. 300 bis 1.000 m<sup>2</sup>/m<sup>3</sup>, eine hohe Wasserhaltekapazität, eine geringe Kompaktierungsneigung und ein geringer Fließwiderstand. Traditionell wird Fasertorf vermischt mit Heidekraut in einem Verhältnis von 1:1 verwendet. Die mikrobielle Aktivität findet im Torf statt, während die Heide als Versteifungsmittel gegen Kompaktierung wirkt und dadurch die Lebensdauer des Füllkörpers verlängert.

Eine Variante des Torf-/Heide-Gemischs ist Pilzkompost, in den 50 % Polystyrolkugeln mit 5 mm Durchmesser als Stützmittel eingemischt sind. Wurzelholz besteht üblicherweise aus Baumwurzeln, Ästen und losen Zweigen. Das Wurzelholz wird durch einen Reißmechanismus, nicht durch gerade Schnitte, in Stücke von üblicherweise 15 cm Länge zerteilt. Dadurch wird effektiv die größtmögliche Oberfläche exponiert, und es wird kein Stützmaterial benötigt. Alle diese Filtermedien haben sich in Industrieanlagen bewährt. Wenn andere Materialien vorgeschlagen werden, können entsprechende Betriebserfahrungen eingeholt werden.

Biofilter lassen sich weiter unterteilen in Erdfilter und Biofilter ohne Erde. Der erdbasierte Biofilter oder der Erdfüllkörper besteht aus einer Schicht poröser Erde, unter der ein Netz von Leitungen verlegt ist, durch das der zu behandelnde Luftstrom geleitet wird. Um den Druckverlust durch den Füllkörper auf ein Minimum zu begrenzen, ist offen strukturierte Erde erforderlich.

#### Erreichbare Umweltvorteile

Weniger Luftemissionen, z. B. Geruch/VOC.

#### Medienübergreifende Auswirkungen

Entstehung saurer Nebenprodukte, z. B. beim biologischen Abbau von Abgasbestandteilen. Entsorgung des Filtermaterials. In manchen Fällen wird zur Reduzierung der organischen Belastung das benutzte Material kompostiert und dann zur Ausbringung auf landwirtschaftlichen Nutzflächen weitergegeben. Das kondensierte Wasser wird wiederverwendet; andernfalls müsste es behandelt werden.

#### Betriebsdaten

Ein ordnungsgemäß betriebener Biofilter weist üblicherweise Geruchskonzentrationen in der Auslassluft von 150 bis 200 GE/m<sup>3</sup> auf. Der charakteristische Geruch der behandelten Abluft ist ein moderig-feuchter Waldgeruch, der sich stark von dem Geruch der Zuluft unterscheidet. Es können Entzugseffizienzen von bis zu 99,5 % erzielt werden, wobei jedoch der prozentuale Anteil des Entzugs sehr von der Konzentration in der Zuluft abhängt. Es ist unwahrscheinlich, dass am Austritt eine Geruchskonzentration von weniger als 150 GE/m<sup>3</sup> erreichbar ist, sodass eine Geruchskonzentration von 5.000 GE/m<sup>3</sup> am Eintritt eine maximale Effizienz von 97 % darstellen würde.

Im Allgemeinen hängt die Verweildauer, die für einen Biofilter erforderlich ist, von Konzentration und Art der im zu behandelnden Luftstrom vorhandenen Verunreinigungen ab. Aromatische Verbindungen benötigen eine längere Verweildauer als einfachere organische Chemikalien. Als allgemeiner Richtwert wird eine minimale Verweildauer von 20 Sekunden gewählt und auf bis zu 40 Sekunden verlängert, wenn Schadstoffe mit verminderter biologischer Abbaubarkeit vorliegen.

Die Geschwindigkeit beim Durchströmen des Filterfüllkörpers beträgt normalerweise zwischen 0,02 und 0,05 m/s. Die Oberflächenbeladungsrate, mit der die Anlagen oft charakterisiert werden, liegt üblicherweise zwischen 100 und 250 m<sup>3</sup> Gas /m<sup>2</sup> Filterfläche/Stunde.

Die normale Lebensdauer eines Filterfüllkörpers wird oft mit 3 bis 5 Jahren angegeben. Bei den meisten Filtermaterialien, insbesondere bei Torf/Heide, muss der Füllkörper jedoch innerhalb der ersten 18 Nutzungsmonate aufgefüllt werden.

Durch die potenzielle Kompaktierung ist die Maximalhöhe des Filtermediums auf etwa 1,0 bis 1,5 Meter beschränkt. Wenn die verfügbare Fläche begrenzt und deshalb eine größere Höhe erforderlich ist, muss innerhalb des vertikalen Körperquerschnitts eine Zwischenstütze eingebaut werden.

Die Verteilung der Luft im Biofilter ist ein wichtiger Faktor, und die Planung einer Luftkammer wird empfohlen. Dabei soll die vertikale Höhe der Luftkammer mindestens 50 % der Höhe des Filtermaterials betragen.

Der pH-Wert des Filtermaterials in einem Biofilter liegt üblicherweise zwischen 6,5 und 7,5. Dieser Bereich wird von den meisten Bakterien bevorzugt. In manchen Fällen erzeugt der biologische Abbau von Abgaskomponenten saure Nebenprodukte, sodass die Zugabe von Lauge erforderlich sein kann.

Wichtige Eigenschaften des Filtermaterials sind unter anderem ein geringer Druckverlust, eine große Pufferkapazität und ein breites Spektrum vorhandener Mikroorganismen. Um eine gute Effizienz zu gewährleisten, ist ein Feuchtigkeitsgehalt im Filterfüllkörper von etwa 40 bis 60 % erforderlich. Der Füllkörper benötigt regelmäßige Wartung, muss also z. B. frei von Pflanzen, abgesetztem Material und Gasdurchbrüchen gehalten werden, damit eine optimale Effektivität gewährleistet ist.

Ein vollständiger Austausch des Materials ist nur nötig, wenn der Abbau der organischen Materie so weit fortgeschritten ist, dass der erforderliche Luftdurchsatz nicht mehr erreicht werden kann. Damit das Filtermaterial ausgetauscht werden kann, muss die Vorrichtung so geplant und gebaut sein, dass das Gitter für Fahrzeuge zugänglich ist oder der Filter mit einem mobilen Greifer gewartet werden kann. Wenn der Biofilter in mehrere Segmente unterteilt ist, muss er für Wartungsarbeiten nicht vollständig außer Betrieb genommen werden.

Je nach Art des vorangehenden Prozesses kann ein Notgasauslass in die Luft installiert werden, der mit einem Temperaturfühler am Gaseintritt in den Biofilter verbunden ist. Der Steuermechanismus wird so eingestellt, dass die Abgase unter Umgehung des Biofilters direkt in die Luft abgelassen werden, wenn die Temperatur am Eintritt in den Biofilter für einen zuvor festgelegten Zeitraum, z. B. vier Stunden, 45 °C übersteigt. Wenn ein solches System eingesetzt wird, werden die Abgase unbehandelt abgegeben, sodass die Bedingungen, die zu einer solchen Umgehung führen, vermieden werden müssen. Es wird auch empfohlen, Indikatoren für die Temperatur und für den Druckverlust an verschiedenen Stellen des Füllkörpers anzubringen.

Staub und Fette müssen unter Umständen vor dem Filter entfernt werden, um eine potenzielle Verstopfung, die zu einem stärkeren Druckverlust und einem Nachlassen der Verfahrenseffizienz führen würde, zu vermeiden.

Füllkörper mit Erde werden üblicherweise unterirdisch errichtet; dabei muss sorgfältig darauf geachtet werden, dass die Unterseite des Erdfilters oberhalb des Grundwasserspiegels liegt. Der größte Nachteil des Erdbiofilters ist die übermäßige Verweildauer, die für biologische Prozesse erforderlich ist und im Bereich von 5 Minuten liegt. Das führt zu sehr großen offenen Strukturen, die sehr viel Platz benötigen.

### Anwendbarkeit

Eingesetzt zur Beseitigung biologisch abbaubarer gasförmiger Luftschadstoffe, insbesondere von organischen Schadstoffen und Gerüchen, z. B. im Fischsektor, bei der Kaffeeverarbeitung und in Kläranlagen. Andere Anwendungsbereiche sind die Reinigung von Raum- und Prozessluft beim Trocknen von Bierhefe und in Ölmühlen, die Reinigung von Röstabgasen in der Kakaoherstellung und die Reinigung von Kühlluft in der Tierfutterproduktion.

Biofiltration ist für einen breiten Bereich von Luftströmen geeignet, nämlich bis zu und auch noch über 100.000 m<sup>3</sup>/h, wenn ausreichend Platz vorhanden ist. Als Grenzwert für die Maximalkonzentration von Schadstoffen (gesamter organischer Kohlenstoff: TOC) in der Zufuhrluft wird allgemein ein Wert unter 5.000 mg/Nm<sup>3</sup> angegeben, wobei bei der Beurteilung der Eignung der Biofiltration für einen bestimmten Zweck ein Konzentrationsgrenzwert von 1.000 mg/Nm<sup>3</sup> als Richtwert dienen kann.

Da Abgase aus Industriequellen allgemein eine Vielzahl von Substanzen enthalten, wird ein Pilotanlagentest empfohlen, damit sichergestellt ist, dass eine ausreichende Größe für den Biofilter gewählt wird.

Biofilter sind für Ventilationssysteme geeignet, bei denen ein konstanter Luftstrom aus einem Gefäß oder einem Prozessraum abgezogen wird. Regelmäßig stark kontaminierte Luftströme sind zu vermeiden, sofern es nicht eine ausreichende Verdünnung aus anderen zu behandelnden Quellen gibt.

Diese Technik ist nicht für Lufttemperaturen von über 40 °C geeignet. Wenn längere Zeit, d. h. mehr als 4 Stunden, Temperaturen von mehr als 40 °C herrschen, werden die im Filter vorhandenen Mikroorganismen sterilisiert und der Füllkörper muss neu beimpft werden. Bei Temperaturen unter 10 °C sinkt die biologische Abbaurrate drastisch ab. Die Technik ist nicht bei Luftfeuchtigkeiten unter 95 % anwendbar.

Angaben zufolge kann der Einsatz von Biofiltern in Anlagen der Nahrungsmittelproduktion, die Fertiggerichte und Speiseeis herstellen, aufgrund der Bakterienpopulation im Filtermaterial ein Hygienierisiko darstellen.

#### Wirtschaftliche Aspekte

Relativ hohe Geruchsbeseitigungseffizienz bei im Vergleich zu anderen Behandlungstechniken relativ geringen Kosten. Da das System mit abwärtsgerichteter Strömung eine luftdichte obere Abdeckung benötigt, sind die Investitionskosten hierfür höher als bei der Aufwärtsströmung. Je größer der Biofilter, desto stärker wirkt sich dieser Kostenunterschied aus.

Die spezifischen Investitionskosten für Biofilter in Modularbauweise hängen von der Anlagengröße und dem Konstruktionsstandard ab. Bei kleineren Anlagen, also 200 bis 500 m<sup>3</sup>/h, betragen die Kosten etwa 45 bis 50 EUR/m<sup>3</sup> Abluft. In größeren Anlagen können die Kosten auf 10 bis 15 EUR/m<sup>3</sup> sinken. In diesen Angaben sind die Kosten für das Auffangen der Abluft und die erforderlichen Baukosten nicht enthalten.

Die Betriebskosten bestehen zum größten Teil aus den Energiekosten für den Betrieb von Gebläsen und Befeuchterpumpen. Es entstehen auch Kosten für das zur Befeuchtung benötigte Wasser, die Wartung des Biofilters und den Austausch des Filtermaterials am Ende seiner Lebensdauer. Die Energiekosten belaufen sich auf 0,15 bis 0,225 EUR/1000 m<sup>3</sup> Abluft, wenn man Stromkosten von 0,15 EUR/kWh annimmt. Einschließlich der oben genannten zusätzlichen Kosten beträgt der Preis für die Behandlung von 1000 m<sup>3</sup>/Stunde Abluft dann 0,225 - 0,30 EUR.

Erdfilter haben im Vergleich zu anderen Behandlungstechniken eine potenziell hohe Geruchsbeseitigungseffizienz bei relativ geringen Kosten.

#### Anlass für die Umsetzung

Vermeidung von Beschwerden von Gerüchen und Einhaltung gesetzlicher Vorgaben.

#### Beispielanlagen

In der Nahrungsmittelproduktion weit verbreitet (ein Beispiel aus dem Kaffeesektor wird in Abschnitt 4.7.8.3 gegeben).

#### Referenzliteratur

[65, Germany, 2002]

### **4.4.3.10.2 Biowäscher**

#### Beschreibung

Biowäscher sind Absorber, in denen ein intensiver Stoffaustausch zwischen dem verunreinigten Gas und dem Absorptionsmittel stattfindet. Die Mikroorganismen sind entweder in der Auffangflüssigkeit fein verteilt, oder sie werden als Schicht auf die Absorberstrukturen oder den Tropffilter aufgebracht. Dem Absorber wird ein Tropfenabscheider angeschlossen, der die gasförmige und flüssige Phase voneinander trennt. Im nachfolgenden Schritt zur Regeneration des Absorptionsmaterials werden die Abgasbestandteile, die in die Flüssigphase absorbiert wurden, aus dem Absorptionsmittel entfernt. Abgase, die hohe Partikelkonzentrationen enthalten, müssen erst einer Staubentfernung unterzogen werden, bevor sie in den Biowäscher geleitet werden können.

Die Technik besteht im Wesentlichen aus einem Schütttschichtabsorber, der in der Schütttschicht und in der Senkgrube eine Bakterienpopulation enthält. Das verunreinigte Gas wird im Turm aufwärts geleitet, und zwar gegen einen Wasserstrom, der eine Bakterienpopulation enthält. Die Bakterien haften am Füllkörper in ähnlicher Weise wie an einem Tropffilter an, der zur Abwasserbehandlung verwendet wird (siehe Abschnitt 4.5.3.1.5). Für Bakterienwachstum und Synthese benötigte Nährstoffe werden der Senkgrube in regelmäßigen Abständen zugesetzt. Ein typisches Schema für einen Biowäscher ist in Abbildung 4.33 dargestellt.

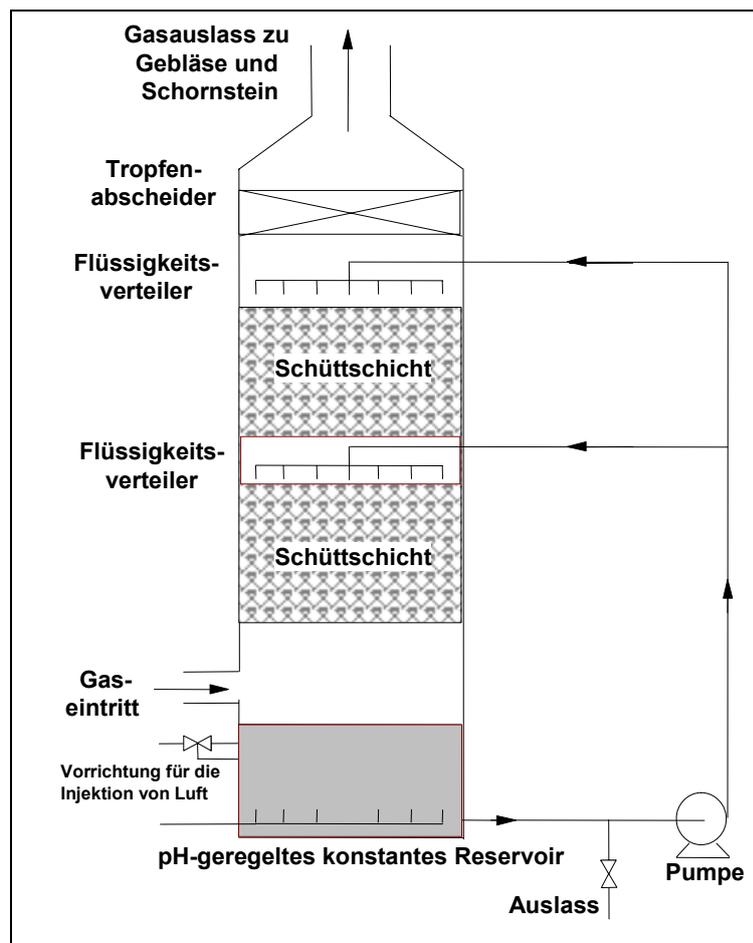


Abbildung 4.33: Schema eines Biowäschers

Erreichbare Umweltvorteile

Weniger Luftemissionen, z. B. Geruch/VOC.

Medienübergreifende Auswirkungen

Biowäscher verbrauchen mehr Energie als Biofilter, da zusätzlich zur Luftbewegung auch Wasser umgewälzt wird. Entsorgung des Filtermaterials.

Betriebsdaten

Die Größe des Biowäschers wird nicht durch den zu behandelnden Luftstrom begrenzt, auch wenn ab einer gewissen Größe ein Einzelturm besser durch zwei parallele Systeme ersetzt wird. Als Grenzwert für die Maximalkonzentration von Schadstoffen (gesamter organischer Kohlenstoff: TOC) in der Zufuhrluft wird allgemein ein Wert unter 5.000 mg/Nm<sup>3</sup> angegeben, wobei bei der Beurteilung der Eignung der Biowäsche für einen bestimmten Zweck ein Konzentrationsgrenzwert von 1.000 mg/Nm<sup>3</sup> als Richtwert dienen kann.

Der biologische Abbau erfolgt relativ langsam, sodass die Betriebsbedingungen von entscheidender Bedeutung sein können. Biowäscher arbeiten normalerweise mit einer Verweildauer von 5 bis 15 Sekunden, je nach zu behandelndem Luftstrom. Biowäscher erfordern eine viel kleinere Bodenfläche als Biofilter.

Anwendbarkeit

Zur Beseitigung von biologisch abbaubaren gasförmigen Luftschadstoffen, insbesondere von organischen Schadstoffen und Gerüchen, verwendet. Theoretisch können Biowäscher überall eingesetzt werden, wo die biologische Oxidation eine ausreichende Lösung eines Emissionsproblems darstellt, und sind daher für ähnliche Anwendungen wie Biofilter geeignet; Biofilter sind jedoch weiter verbreitet. Diese Technik ist nicht für Lufttemperaturen von über 40 °C geeignet.

Wirtschaftliche Aspekte

Relativ hohe Geruchsbeseitigungseffizienz bei im Vergleich zu anderen Behandlungstechniken relativ geringen Kosten.

Referenzliteratur

[34, Willey A R and Williams D A, 2001, 65, Germany, 2002]

**4.4.3.11 Thermische Behandlung von Abgasen**

Bestimmte gasförmige Schadstoffe und Gerüche können bei hohen Temperaturen oxidiert werden. Die Reaktionsgeschwindigkeit steigt exponentiell mit der Temperatur an.

Zu den oxidierbaren Schadstoffen zählen sämtliche organischen Verbindungen sowie anorganische Stoffe wie Kohlenmonoxid und Ammoniak. Eine vollständige Verbrennung vorausgesetzt, reagieren Kohlenstoff und Wasserstoff mit Sauerstoff unter Bildung von Kohlendioxid und Wasser. Eine unvollständige Verbrennung kann zu neuen Schadstoffen wie Kohlenmonoxid und zu ganz oder teilweise nicht oxidierten organischen Verbindungen führen. Wenn das Abgas Elemente wie Schwefel, Stickstoff, Halogene und Phosphor enthält, entstehen bei der Verbrennung anorganische Schadstoffe wie Schwefeloxide, Stickoxide und Halogenwasserstoffe, die anschließend mit anderen Verfahren der Abgasreinigung entfernt werden müssen, wenn ihre Konzentrationen zu hoch sind. Dadurch werden die möglichen Anwendungsbereiche für die Schadstoffverbrennung eingeschränkt.

Es bestehen eine Reihe von Sicherheitsanforderungen, insbesondere:

- Es muss ein Schutz gegen Flammenrückschlag zwischen der thermischen Nachverbrennungsanlage und dem zu behandelnden Gasstrom bestehen. Das lässt sich im Allgemeinen durch ein Flammrückschlagsiegel oder eine Wasservorlage erzielen.
- Beim Hochfahren muss die Nachverbrennungsanlage vor dem Zünden des Brenners mit einer Menge Luft, die dem fünffachen Anlagenvolumen entspricht, durchgespült werden. Jeder Neuzündung der Brenner während des Betriebs muss eine Brennerspülphase vorangehen.
- Wenn die Luft viel Lösemittel enthält, muss eine Risikobewertung erfolgen.

**4.4.3.11.1 Thermische Oxidation von Abgasen**Beschreibung

Damit die abzubauenen Verbindungen im Luftstrom vollständig oxidiert werden, müssen sie lange genug und bei ausreichend hoher Temperatur mit ausreichend Sauerstoff in Berührung kommen. Die schnelle Oxidation von organischen Verbindungen erfolgt, wenn die Gastemperatur in der thermischen Nachverbrennungsanlage 200 – 400 °C über der Selbstentzündungstemperatur der vorliegenden chemischen Substanzen gehalten werden kann. Bei der thermischen Oxidation erfolgt die Umwandlung der Schadstoffe bei hohen Temperaturen, z. B. > 600 °C.

Neben der Eignung der zu beseitigenden Verbindungen für die thermische Oxidation ist auch zu berücksichtigen, ob zur Senkung der Brennstoffkosten Wärme aus dem thermischen Oxidationsprozess rückgewonnen werden kann. Da Luftemissionen in der Nahrungsmittelproduktion selten Konzentrationen von organischen Stoffen im Bereich geringer Explosionskonzentrationen aufweisen, werden überwiegend konventionelle thermische Nachverbrennungsanlagen eingesetzt, bei denen ein direkter Flammenkontakt mit dem zu behandelnden Luftstrom besteht. In Fällen, in denen hohen Konzentrationen organischer Stoffe oberhalb der jeweiligen Explosionsgrenzwerte auftreten, kann ein flammenloses System erforderlich sein. Bei diesen Systemen wird zum Erwärmen des Luftstroms ein Heizmedium eingesetzt und so der direkte Kontakt des Luftstroms mit der Flamme vermieden.

Thermische Nachverbrennungsanlagen mit direkter Flamme werden normalerweise bei Temperaturen zwischen 700 und 900 °C betrieben. Die Reaktionstemperatur hängt von der Art des Schadstoffs ab. Sie kann niedriger sein, aber bei nicht leicht zu oxidierenden Stoffen wie organischen Halogenverbindungen kann sie auch über 1.000 °C liegen. Bei übelriechenden Verbindungen wird im Allgemeinen eine Temperatur von 750 – 800 °C gewählt. In Tabelle 4.39 sind die Zustandsbedingungen der Gerätstufen einer thermischen Nachverbrennungs-

anlage angegeben. Ein typisches Schema einer thermischen Nachverbrennungsanlage ist in Abbildung 4.34 dargestellt.

| Gerätestufen       | Betriebsbedingungen  |
|--------------------|--|
| Brennstufe         | Der Brennstoff wird mit sauberer Luft oder einem Teil der kontaminierten Luft verbrannt, wobei eine Flamme mit einer Temperatur von üblicherweise zwischen 1.350 und 1.500 °C entsteht |
| Mischstufe         | Zur Gewährleistung ausreichender Turbulenz und damit der Durchmischung des Prozessgases, damit es eine gleichmäßige Temperatur annimmt   |
| Verbrennung        | Die Gase werden auf der Verbrennungstemperatur gehalten, bis die Oxidation abgeschlossen ist, was normalerweise 0,5 bis 1,0 Sekunden dauert  |
| Wärmerückgewinnung | Senkt Betriebskosten und Brennstoffverbrauch   |

Tabelle 4.39: Betriebsbedingungen bei verschiedenen Stufen der thermischen Oxidation

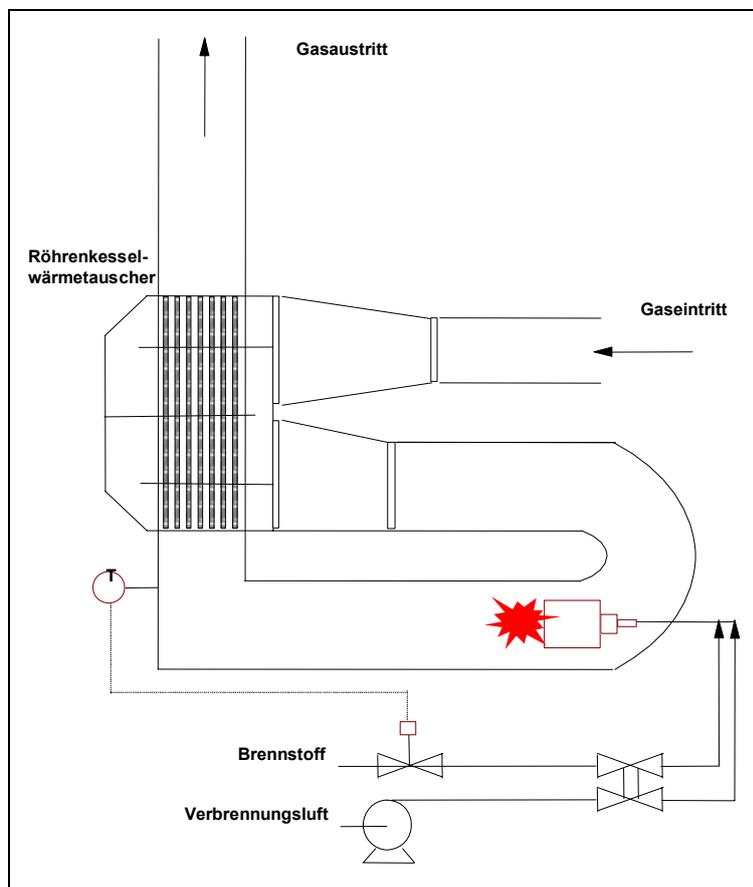


Abbildung 4.34: Schema einer thermischen Nachverbrennungsanlage

**Brenner** lassen sich in ein- und mehrflammige Brenner unterteilen. Hinsichtlich der Form gibt es Brenner mit laminarer Strömung, Düsenbrenner und Wirbelbrenner. In Sonderfällen kann der Brenner durch ein elektrisches Heizsystem ersetzt werden. Der für die Verbrennung erforderliche Sauerstoff kann aus der Luft, aus dem zu behandelnden Luftstrom oder auch aus beiden stammen. Mögliche Ergänzungsbrennstoffe sind leichtes Heizöl, Erdgas und Flüssiggas (LPG). Es muss sorgfältigst darauf geachtet und überwacht werden, dass die Flamme nicht von eventuell im Luftstrom vorhandenem Wasserdampf gelöscht wird, was eine schlechte Verbrennung bedeuten würde.

Der Brenner kann entweder ein Vormischbrenner sein, bei dem der Brennstoff vor dem Passieren der Düsen mit der Verbrennungsluft vermischt wird, oder ein Diffusionsbrenner, bei dem der Brennstoff nach dem Passieren der Düsen mit der Verbrennungsluft vermischt wird. Die meisten Brenner sind vom Diffusionsbrenner.

Das **Durchmischen** des Gasstroms kann auf mehrere Arten erreicht werden, z. B. durch natürliche Diffusion, durch Aufprallmechanismen oder durch Umlenkbleche zur Erzeugung von Strömungsänderungen. Hersteller von Systemen, die mit geringem NO<sub>x</sub>-Ausstoß arbeiten, bauen oft verschiedene Rückmischabschnitte ein, die Temperaturanstiege auf Werte deutlich oberhalb der Mischtemperatur verhindern sollen.

Die **Verbrennungskammer**, in der die Oxidationsreaktion stattfindet, muss für hohe thermische Belastungen ausgelegt sein. Verbrennungskammern sind aus hitzebeständigem Metall hergestellt oder mit einem Metallmantel und feuerfester Auskleidung versehen. Die Abmessungen der Verbrennungskammer müssen ausreichend sein, um die gewünschte Verweildauer zu ermöglichen und Raum für die Länge der Flamme zu bieten, ohne diese zu ersticken.

Fast immer ist eine Form der **Wärmerückgewinnung** lohnend, um Betriebskosten und Brennstoffverbrauch zu senken. Die Wärmerückgewinnung erfolgt üblicherweise in einem Röhrenkesselwärmetauscher, der die kontinuierliche Übertragung von Wärme zum Vorwärmen des zugeführten Gasstroms erlaubt. Diese Art von System wird als Rekuperator bezeichnet, wobei eine planmäßige Wärmerückgewinnung von 70 – 80 % üblich ist.

Die Wärmerückgewinnung kann auch mit einem regenerativen System, bei dem zwei Wärmetauscher mit Keramikbetten verwendet werden, erfolgen. Dabei wird das eine Bett durch direkten Kontakt mit dem Abgas erwärmt, während das andere dem Vorwärmen des einströmenden Gases dient. Das System wird so betrieben, dass die Betten zwischen Wärm- und Kühlfunktion wechseln. Das Wärmerückgewinnungspotenzial eines solchen Systems ist höher als das eines Rekuperators; übliche Planungsgrundlage ist eine Wärmerückgewinnung von 80 – 90 %. Alternativ zu dieser Systemart kann auch eine Umlaufflüssigkeit verwendet werden.

Wärme kann auch über einen Abwärmekessel rückgewonnen werden, in dem die behandelten Abgase genutzt werden, um Dampf zur Nutzung in anderen Teilen der Anlage oder an anderer Stelle des Standorts zu erzeugen. Der Betrieb der thermischen Nachverbrennungsanlage fällt zeitlich nicht immer mit dem Dampfbedarf zusammen, sodass die Integration kompliziert sein kann.

Es besteht auch ein Potenzial für eine sekundäre Wärmerückgewinnung, wenn das behandelte Abgas aus der ersten Stufe der Wärmerückgewinnung dazu benutzt wird, Wasser für die Raumbeheizung zu erwärmen.

Angaben zufolge kann die Verbrennungswärme in einem Kreuzstromwärmetauscher rückgewonnen und anstelle von Dampf für den Garprozess verwendet werden. Angaben zufolge werden durch die Verbrennung von Rauchgasen aus Gar-/Räucheröfen sämtliche Geruchsprobleme in der engeren Umgebung beseitigt.

Weitere Informationen zu dieser Technik, ihre tatsächliche Leistung und ein Vergleich mit anderen Techniken zur Minderung von Luftverunreinigungen finden sich im Referenzdokument zu „Abwasser- und Abgasbehandlung/-management“ [217, EC, 2003].

#### Erreichbare Umweltvorteile

Weniger Gas- und Geruchsemissionen.

#### Medienübergreifende Auswirkungen

Beim Oxidationsprozess können unerwünschte Verbrennungs-Nebenprodukte, z. B. hohe Konzentrationen von NO<sub>x</sub> und CO<sub>2</sub>, entstehen. Mit steigender Reaktionstemperatur vergrößert sich insbesondere das Potenzial höherer NO<sub>x</sub>-Konzentrationen. Allgemein ist es von Vorteil, einen Brenner mit geringem NO<sub>x</sub>-Ausstoß zu wählen.

Alle schwefelhaltigen Verbindungen im übelriechenden Gasstrom führen zu SO<sub>2</sub>-Emissionen, und die Möglichkeiten zu deren Minimierung sind zu erwägen. Das Vorhandensein von Chloriden im übelriechenden Luftstrom muss möglicherweise überprüft werden, da sich potenziell saure Gase wie HCl bilden können. Dadurch können nicht nur Emissionen entstehen, sondern möglicherweise auch Korrosionsprobleme an den Geräten. Wenn halogenierte VOC vorliegen, können besondere Bedingungen zur Unterbindung der Dioxinbildung erforderlich sein. Normalerweise ist die Dioxinbildung bei der Verbrennung von Abgasströmen jedoch vernachlässigbar [217, EC, 2003].

Energieverbrauch, z. B. Brennstoffverbrauch zum Betrieb der Nachverbrennungsanlage.

Betriebsdaten

Thermische Nachverbrennungsanlagen arbeiten erst effektiv, wenn sie die Verbrennungstemperatur der Schadstoffe erreicht haben, die sie zerstören sollen. Sie müssen also hochgefahren werden, bevor sie tatsächlich gebraucht werden.

Eine sachgerecht geplante und betriebene thermische Nachverbrennungsanlage kann eine Geruchsbeseitigungseffizienz von fast 100 % erreichen. Die Effizienz dieser Technik ist von der Intensität der Geruchsemissionen unabhängig.

Übelriechende Luftströme, die erhebliche Mengen an partikulärem Material enthalten, erfordern im Allgemeinen eine Vorbehandlung, bevor sie der thermischen Oxidation unterzogen werden. Das ist insbesondere dann von Bedeutung, wenn ein System zur Wärmerückgewinnung installiert wurde, da es ansonsten leicht zu einer Verunreinigung des Wärmetauschers kommen kann.

Ein hoher Wasserdampfanteil im Luftstrom wird zwar nicht als Problem für den Prozess angesehen, aber der Brennstoffbedarf ist in einem solchen Fall größer als für die Erwärmung von trockener Luft. In der Praxis wird Wasserdampf normalerweise nicht aus einem Luftstrom entfernt und der zusätzliche Brennstoffbedarf wird in die wirtschaftlichen Gesamtüberlegungen zum Einsatz der thermischen Oxidation als Technik einbezogen.

Durch thermische Oxidation von Abgasen lassen sich VOC-Konzentrationen von <1 – 20 mg/m<sup>3</sup> erzielen [217, EC, 2003].

Bei einer norwegischen Untersuchung zum Räuchern von Wurstwaren wurden nach der thermischen Oxidation von Räuchergasen aus einem Gar-/Räucherschrank die folgenden Emissionen gemessen: 7 mg TOC/m<sup>3</sup> oder 0,2 mg TOC/t Wurst. Das Gas enthielt kein CO.

In einer als Beispielanlage dienenden Räucherammer mit einer Jahresproduktion von etwa 3.000 Tonnen Räucherprodukten werden die Räucherabgase in einer thermischen Nachverbrennungsanlage mit direkter Flamme verbrannt. Das Abgas aus den „rauchfreien“ Prozessphasen, für das keine Emissionsminderung erforderlich ist, wird nicht behandelt. Das System gilt als robuste Abgasbehandlung, die nur wenig Wartung erfordert.

Die thermische Nachverbrennungsanlage wird auf Betriebstemperatur geheizt, bevor die Rauchgeneratoren in Betrieb genommen werden. Während des Räucherns drückt das Abgasgebläse das mit Rauch befrachtete Abgas durch eine Abgasumgehungsclappe in einen Vorwärmer. Dort wird das verunreinigte Gas auf 300 – 350 °C erwärmt, bevor es in die Verbrennungskammer gelangt, wo es mit den heißen Gasen aus dem Gasbrenner vermischt wird. Nach der Behandlung wird das saubere Gas mit einem integrierten Wärmetauscher zum Vorwärmen des verunreinigten Gases verwendet. Vor der Abgabe in die Luft über einen Schornstein wird es auf 400 – 450 °C abgekühlt.

In Tabelle 4.40 sind die technischen Daten für die thermische Oxidation mit direkter Flamme in der als Beispielanlage dienenden Räucherammer angegeben. Herkunft und Prozessmanagement des Abgases aus dieser Räucherammer sind in Abbildung 4.35 als Flussdiagramm dargestellt.

| <b>Abmessungen</b>                 |                                      |
|------------------------------------|--------------------------------------|
| Gesamtlänge einschließlich Brenner | 4.250 mm                             |
| Gesamtlänge ohne Brenner           | 3.750 mm                             |
| Durchmesser                        | 1.150 mm                             |
| Anschluss für verunreinigtes Gas   | 200 x 200 mm oder 200 mm Durchmesser |
| Anschluss für sauberes Gas         | 300 mm                               |
| Gewicht                            | ungefähr 1.250 kg                    |
| <b>Nennwerte für Anschlüsse</b>    |                                      |
| Brennstoff                         | Öl                                   |
| Stromversorgung                    | 220 V/50 Hz (etwa 1 kW)              |
| Abgasgebläse                       | 380 V/50 Hz (etwa 4 kW)              |

**Tabelle 4.40: Technische Daten einer thermischen Nachverbrennungsanlage mit direkter Flamme in einer Räucherammer**

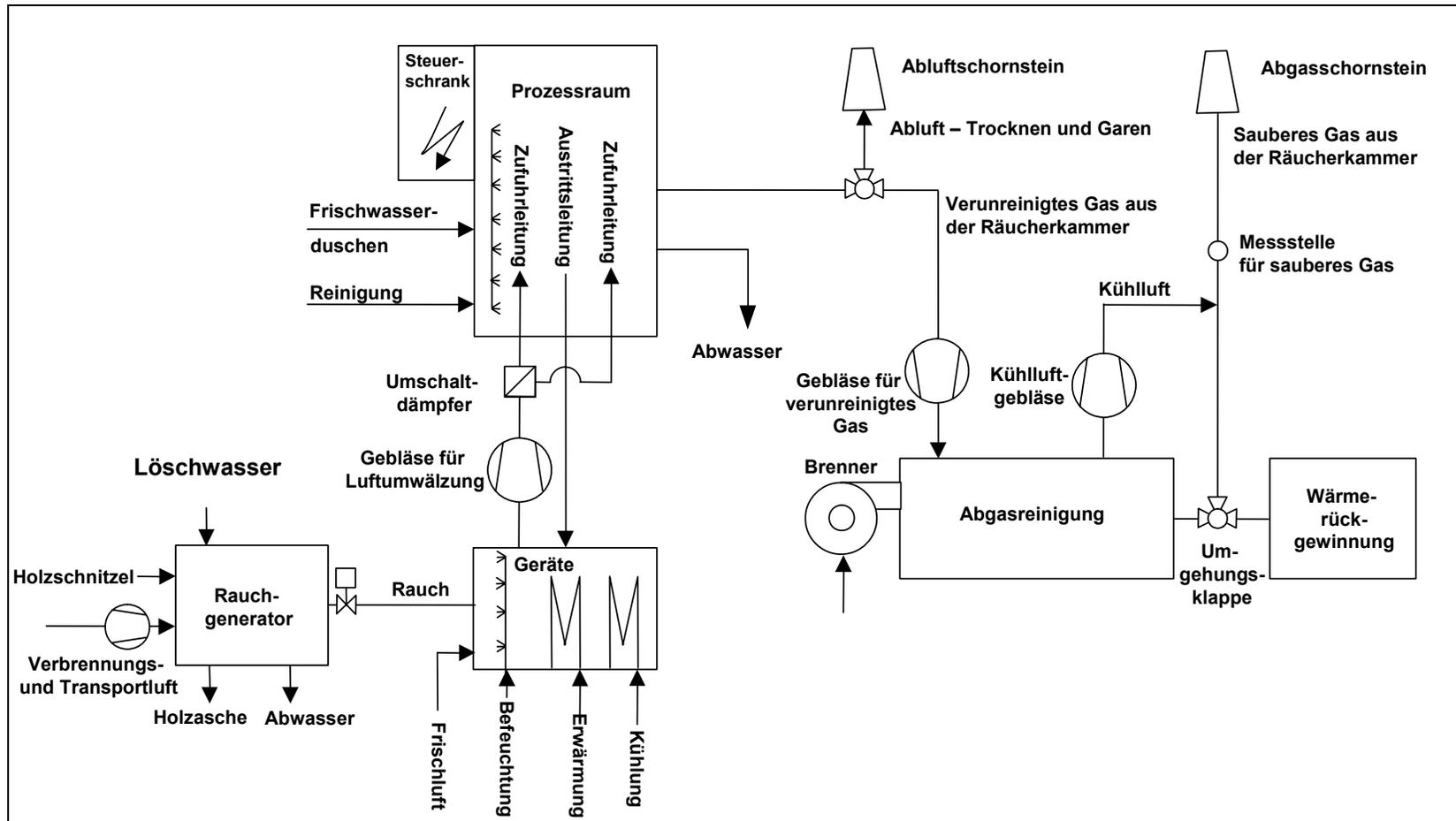


Abbildung 4.35: Flussdiagramm zu Ursprung und Prozessmanagement des Rauchgases aus dem Abgasreinigungssystem einer Räucher-kammer

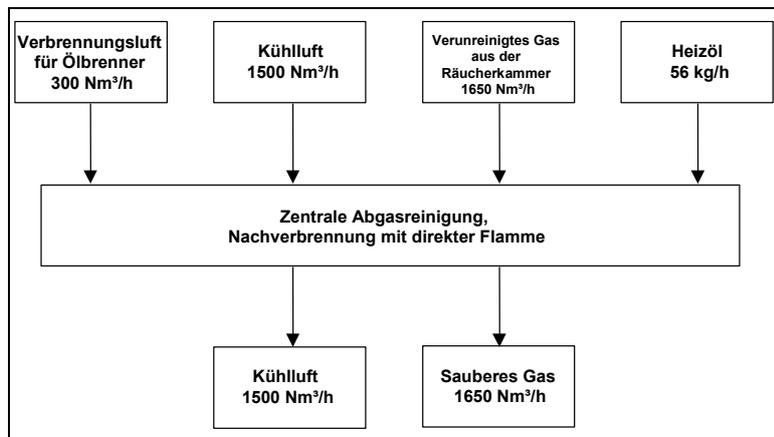
In der als Beispiel dienenden Räucherammer sind alle Räuchereinheiten, unabhängig von ihrer Größe, mit einem Rauchgenerator ausgestattet. Die Räucherintensität wird durch die Räucherzeit bestimmt, die ungefähr 60 – 120 Minuten pro Charge beträgt. Der Volumenstrom pro Rauchgenerator beträgt 200 Nm<sup>3</sup>/h, was bei 11 Räuchereinheiten einem Gesamtvolumenstrom von etwa 2.300 Nm<sup>3</sup>/h entspricht. Unter Annahme eines realistischen Parallelbetriebsfaktors von 75 % beträgt der tatsächliche Volumenstrom 1.650 Nm<sup>3</sup>/h. In Tabelle 4.41 sind die technischen Daten der betreffenden thermischen Nachverbrennungsanlage mit direkter Flamme angegeben.

| Parameter                      | Werte   | Anmerkungen   |
|--------------------------------|---|---|
| Abgasvolumenstrom              | 2.300 m <sup>3</sup> /h   | Normalbedingungen (d. h., 0 °C, 1013 mbar, trocken)           |
| Brennerkapazität               | 600 kW  | Die Kapazität wird laufend moduliert                          |
| Substanzkonzentration im Abgas | k. A. über erreichte Werte (<50 mg/Nm <sup>3</sup> TOC ≤0,115 kg/h) | 2.300 Nm <sup>3</sup> /h x 50 mg/Nm <sup>3</sup> = 0,115 kg/h |

**Tabelle 4.41: Technische Daten einer thermischen Nachverbrennungsanlage mit direkter Flamme in einer Räucherammer**

Angaben zufolge wird bei 620 bis 660 °C eine vollständige Geruchs-beseitigung erzielt, und im Allgemeinen wird TOC mit einer nicht näher bezeichneten Konzentration unterhalb von 50 mg/Nm<sup>3</sup> abgegeben. Die thermische Oxidation mit direkter Flamme kann bei Temperaturen bis zu 1.000 °C betrieben werden. Die Effektivität der Technik hängt von verschiedenen Parametern wie Betriebstemperatur, Verweildauer und Durchmischungsbedingungen in der Verbrennungskammer ab. Es können problemlos TOC-Konzentrationen von weniger als 10 mg/Nm<sup>3</sup> erreicht werden.

Abbildung 4.36 zeigt die Stoffbilanz des Abgasbehandlungssystems als Diagramm der eingesetzten und erzeugten Stoffe.



**Abbildung 4.36: Massenbilanz eines Systems zur Behandlung von Abgasen durch thermische Oxidation mit direkter Flamme**

Anwendbarkeit

Wird zur Beseitigung von VOC/Gerüchen eingesetzt. Die thermische Oxidation hat den Vorteil, dass sie fast immer als Methode zur Geruchsminderung eingesetzt werden kann, da die meisten übelriechenden Substanzen sich bei hohen Temperaturen zu nicht übelriechenden Produkten oxidieren lassen, während die Anwendung anderer Verfahren stärker eingeschränkt ist.

Im Allgemeinen wird die thermische Oxidation jedoch nur zur Behandlung geringer Volumen von weniger als 10.000 Nm<sup>3</sup>/h eingesetzt, da die Kosten für das Erwärmen größerer volumetrischer Luftströme höher sind. Sie ist für übelriechende Ströme mit schwankenden Schadstoffkonzentrationen geeignet, und auch schwankende volumetrische Durchsätze können behandelt werden.

In Gemüsetrocknungsanlagen können in der Erde vorhandene Alkalimetalle eine vorzeitige Abnutzung der keramischen Medien verursachen, die für die regenerative Wärmerückgewinnung genutzt werden.

Wirtschaftliche Aspekte

Diese Technik erfordert hohe Kapitalinvestitionen, aber die Hauptrolle bei der Eignungsanalyse der thermischen Oxidation spielen die mit dem Brennstoffbedarf verbundenen Betriebskosten. Durch den Einsatz rekuperativer oder regenerativer Wärmerückgewinnungssysteme lassen sich die Effizienz der Technik steigern und die laufenden Kosten senken. Alle Räucheröfen können nachträglich mit der Technik ausgestattet werden, wobei die Kosten unterschiedlich hoch ausfallen. Räucheröfen sind mit eingebauter Ausstattung für die thermische Oxidation erhältlich.

Beispielanlagen

Wird in mindestens einer Räucherkammer in Deutschland und in Räucherkammern in den nordeuropäischen Ländern eingesetzt.

Referenzliteratur

[34, Willey A R and Williams D A, 2001, 41, Nordic Council of Ministers, 2001, 65, Germany, 2002]

**4.4.3.11.2 Oxidation von Abgasen in einem schon vorhandenen Kessel**Beschreibung

Möglicherweise können die übelriechenden Gase in einen am Standort vorhandenen Kessel geleitet werden. Dadurch ergibt sich der Vorteil der Verwendung bereits vorhandener Geräte, und die Investitionskosten für eine andere Behandlungsmöglichkeit können vermieden werden. Das Funktionsprinzip gleicht im Wesentlichen dem einer eigens errichteten thermischen Nachverbrennungsanlage.

Der übelriechende Abgasstrom wird zum Gebläse für den Verbrennungsluftstrom des Kessels oder Kesselhauses und dann zum Kessel geleitet. Er liefert Sauerstoff für den Verbrennungsprozess und die übelriechenden Substanzen werden vernichtet.

Ob ein vorhandener Kessel überhaupt genutzt werden kann, hängt größtenteils vom Volumen der zu behandelnden übelriechenden Luft im Verhältnis zum Verbrennungsluftbedarf des Kessels bei maximaler und minimaler Belastung ab. Wenn das Volumen der übelriechenden Luft wesentlich kleiner ist als der Verbrennungsluftbedarf ist, stellt es wahrscheinlich kein Problem dar. Das gesamte Volumen der übelriechenden Luft könnte einfach durch das Verbrennungsgebläse geleitet werden. Meistens sind die Betriebsbedingungen jedoch so, dass der Kessel in einem zyklischen Modus arbeitet, wobei er auf ein Dampfdrucksignal reagiert.

Die möglichen Auswirkungen auf den Kesselbetrieb müssen vollständig betrachtet werden. Die Sicherheitsmerkmale, die bei der Umleitung eines übelriechenden Ausstoßes in einen Kessel erforderlich sind, sollten im Wesentlichen für den bereits bestehenden Kesselbetrieb vorhanden sein. Zusätzliche Flammrückschlagsiegel oder Wasservorlagen können erforderlich sein, um einen Flammenrückschlag zwischen dem Kessel und dem zu behandelnden Gasstrom zu verhindern.

Erreichbare Umweltvorteile

Angaben zufolge sehr effizient und bei sachgerechtem Betrieb genau so effizient in der Beseitigung von Gerüchen, einschließlich intensiver Gerüche, wie andere Verbrennungsverfahren.

Medienübergreifende Auswirkungen

Energieverbrauch. Der Brennstoffverbrauch kann ansteigen, da der Kessel möglicherweise weiterbetrieben werden muss, wenn er ansonsten nicht benötigt worden wäre.

Betriebsdaten

Der Normalbetrieb eines Kessels dient der Erzeugung von soviel Dampf, wie in der Anlage benötigt wird; dieser Bedarf wird kontinuierlich durch das Dampfdrucksignal am Kesselauslass ermittelt. Wenn der Dampfdruck auf den Sollwert ansteigt, wird die Brennstoffzufuhr zum Brenner gedrosselt. Der Verbrennungsluftstrom, der elektrisch oder mechanisch an die Brennstoffzufuhr rate gekoppelt ist, wird ebenfalls gedrosselt, damit die Verbrennungsbedingungen optimal bleiben. Wenn der Verbrennungsluftstrom in einer solchen Situation geringer ist als das Volumen der zu behandelnden übelriechenden Luft ist, müsste die Kesselsteuerung geändert werden. Auch die Kenntnis des Sauerstoffgehalts der übelriechenden Luft, wenn er unter 21 % liegen könnte, kann bei der ersten Abschätzung der Machbarkeit hilfreich sein.

Die Steuerung könnte so geändert werden, dass sie nicht mehr vom Dampfdruck, sondern vom Volumenstrom der Verbrennungsluft abhängig wäre. Der Volumenstrom der Verbrennungsluft würde dann auf ein Minimum eingestellt, also auf das Volumen der zu behandelnden übelriechenden Luft, und so würden wiederum eine minimale Brennstoffzufuhr und eine minimale Feuerungsrate vorgegeben. Wenn der Sollwert des Dampfdrucks erreicht ist, schaltet der Kessel auf den Betrieb bei minimalem Volumenstrom der Verbrennungsluft um, und die nicht benötigte Wärme wird durch den Kesselschornstein abgegeben. Ein Schlüsselaspekt bei der Bewertung ist die Feststellung des Prozentsatzes der Betriebszeit, während der der Kessel mit einer Verbrennungsluftzufuhr arbeitet, die unter dem Volumenstrom der übelriechenden Luft liegt, damit die zusätzlichen Brennstoffkosten berechnet werden können.

Eine wichtige anfängliche Überlegung ist die Frage, ob der Kessel normalerweise in Betrieb ist, wenn die übelriechenden Gase entstehen. Das ist wahrscheinlich in den meisten Betrieben der Fall.

### Anwendbarkeit

Wird zur Beseitigung von gasförmigen Schadstoffen und Gerüchen eingesetzt. Geeignet für Gerüche mit geringem Volumen und hohen Konzentrationen.

### Wirtschaftliche Aspekte

Die Möglichkeit der Nutzung eines bestehenden Kesselhauses hat wirtschaftliche Vorteile sowohl hinsichtlich der Investitions- als auch der Betriebskosten.

### Anlass für die Umsetzung

Erfüllung gesetzlicher Bestimmungen.

### Referenzliteratur

[34, Willey A R and Williams D A, 2001]

#### **4.4.3.11.3 Katalytische Oxidation von Abgasen**

##### Beschreibung

Die katalytische Oxidation ähnelt der thermischen Oxidation. Der grundlegende Unterschied besteht darin, dass die Oxidationsreaktion in Gegenwart eines Katalysators stattfindet, nicht in freier Luft. Hauptvorteil der katalytischen Oxidation ist die wesentlich geringere Betriebstemperatur, nämlich zwischen 250 und 500 °C.

Wie auch bei der Adsorption, müssen die Reaktanden für die heterogene Gasreaktion zuerst zu den inneren Oberflächen der normalerweise porösen Katalysatoren transportiert werden. Da es einen allgemeinen Mangel an Daten zu den Stoffen gibt, wie z. B. die Konstante der Reaktionsgeschwindigkeit und der Diffusionskoeffizient, werden Reaktoren meist auf der Grundlage empirischer Daten geplant.

Die Hauptbestandteile eines katalytischen Verbrennungssystems sind ein Hilfsbefeuerungsgerät, ein Wärmetauscher und ein Reaktor mit Katalysator. Ein typisches Schema für eine katalytische Nachverbrennungsanlage ist in Abbildung 4.37 dargestellt.

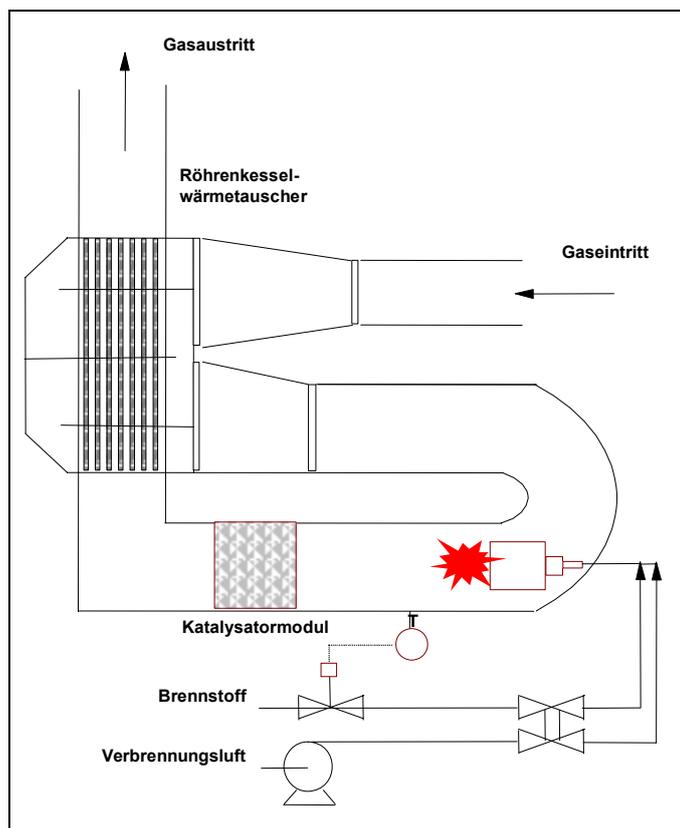


Abbildung 4.37: Schema einer katalytischen Nachverbrennungsanlage

Der Luftstrom tritt in das System ein und wird in einem herkömmlichen Röhrenkesselwärmetauscher vorgewärmt. Der vorgewärmte Zufuhrstrom wird dann über einen Brenner weiter auf die gewünschte Oxidationstemperatur erhitzt, bevor er zum Katalysator geleitet wird. Die im übelriechenden Luftstrom vorhandenen Verunreinigungen diffundieren zusammen mit Sauerstoff auf die Katalysatoroberfläche. Die Oxidation findet statt und die Oxidationsprodukte werden in den Gasstrom zurückdesorbiert. Diese Übergangsprozesse erfordern eine bestimmte Zeit im Katalysator, wobei die Reaktionsrate stark von der Betriebstemperatur abhängig ist. Der behandelte Gasstrom passiert dann den Wärmetauscher, wo er den eintretenden übelriechenden Luftstrom erwärmt.

Der wichtigste Aspekt eines Katalysatorbettes ist das Verhältnis von Oberfläche zu Volumen und damit der für die Reaktion verfügbare Bereich.

Zu den wirksamen Bestandteilen gehören üblicherweise Metalle der Platingruppe und Oxide der Metalle Co, Cr, Cu, Fe, Mo, Ni, Ti, V und W. Die Hilfsmaterialien sind normalerweise Metalle in Form von Elektroden, gewebten Stoffen oder Netzen, Metalloxide wie  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$  und  $\text{MgO}$  und Minerale wie Bimsstein und Zeolith in modellierten Formen.

Die folgenden Planungsaspekte werden bei der Bewertung der katalytischen Verbrennung als möglicher Minderungsmaßnahme berücksichtigt: Raumgeschwindigkeit, Druckverlust und Temperatur.

Die **Raumgeschwindigkeit** ist definiert als der Kehrwert der Verweildauer des Gases innerhalb des Katalysatorblocks, wenn der volumetrische Luftstrom bei  $0^\circ\text{C}$  ausgedrückt wird. Bei industriellen Anwendungen liegt die Raumgeschwindigkeit üblicherweise zwischen 20.000 und 45.000 m/h. Das entspricht bei normalen Betriebstemperaturen einer Verweildauer im Bereich von 0,03 bis 0,1 Sekunden. Im Wesentlichen ist zwischen der in die Planung einbezogenen Katalysatormenge und der Betriebstemperatur abzuwägen. Je mehr Katalysator, was bedeutet, dass die Raumgeschwindigkeit eher in Richtung 20.000 m/h tendiert, desto geringer ist die Betriebstemperatur, die zur Erzielung einer bestimmten Leistung erforderlich ist. Wenn der zu behandelnde Luftstrom groß ist, besteht die Möglichkeit, einen zusätzlichen Katalysator einzusetzen, um die Brennstoffkosten zu senken, da nur auf eine geringere Betriebstemperatur aufgeheizt werden muss. Eine höhere Katalysatorcharge führt jedoch zu einem stärkeren Druckverlust, was wiederum mehr Leistung des Abzugsgebläses erfordert.

Für den Katalysator gilt eine lineare Beziehung zwischen Volumenstrom und **Druckverlust** durch die laminare Strömung im Katalysator. Die übliche Bauart lässt einen Gesamtsystem-Druckverlust von etwa 500 mm zu. Die Konfiguration des Katalysatorblocks spielt eine wichtige Rolle bei der Minimierung des Druckverlusts und damit der Betriebskosten.

Die katalytische Oxidation ist eine exotherme Reaktion. Es gibt Anlagen, in denen die Temperatur so weit ansteigt, dass die katalytische Nachverbrennungsanlage ohne weitere Brennstoffzugabe von selbst weiterläuft, wenn die Betriebsbedingungen erreicht sind.

Wärmerückgewinnung in der Form, dass die behandelten Gase zum Vorwärmen der einströmenden Gase genutzt werden, ist ein wesentlicher Bestandteil des Prozesses und wird meist in der Planung vorgesehen. Wärmetauscher werden üblicherweise für eine Wärmerückgewinnung von 80 °C ausgelegt, was bei normalen Oxidationstemperaturen effektiv zu einer Abgabetemperatur zwischen 150 und 200 °C führt.

Der Raumbedarf für katalytische Nachverbrennungsanlagen ist geringer als für Abgasverbrennungsanlagen.

### Erreichbare Umweltvorteile

Weniger Gas- und Geruchsemissionen.

### Medienübergreifende Auswirkungen

Beim Verbrennungsprozess können unerwünschte Verbrennungs-Nebenprodukte, z. B. hohe Konzentrationen von NO<sub>x</sub> und CO<sub>2</sub>, entstehen. Mit steigender Reaktionstemperatur vergrößert sich insbesondere das Potenzial höherer NO<sub>x</sub>-Konzentrationen. Allgemein ist es von Vorteil, einen Brenner mit geringem NO<sub>x</sub>-Ausstoß zu wählen. Bei den üblichen Betriebstemperaturen ist die NO<sub>x</sub>-Bildung relativ gering, und es können Werte von 15 mg/Nm<sup>3</sup> erreicht werden.

Alle schwefelhaltigen Verbindungen im übelriechenden Gasstrom führen zu SO<sub>2</sub>-Emissionen, und die Möglichkeiten zu deren Minimierung sind zu erwägen. Das Vorhandensein von Chloriden im übelriechenden Luftstrom muss möglicherweise überprüft werden, da sich potenziell saure Gase wie HCl bilden können. Dadurch können nicht nur Emissionen entstehen, sondern möglicherweise auch Korrosionsprobleme innerhalb der Verbrennungsanlage.

Wenn halogenierte VOC vorliegen, können besondere Bedingungen zur Unterbindung der Dioxinbildung erforderlich sein. Normalerweise ist die Dioxinbildung bei der Verbrennung von Abgasströmen jedoch vernachlässigbar [217, EC, 2003].

Energieverbrauch, z. B. Brennstoffverbrauch zum Betrieb der Verbrennungsanlage.

### Betriebsdaten

Katalytische Nachverbrennungsanlagen arbeiten erst effektiv, wenn sie die Verbrennungstemperatur der Schadstoffe erreicht haben, die sie beseitigen sollen. Sie müssen also hochgefahren werden, bevor sie tatsächlich gebraucht werden.

Durch katalytische Verbrennung von Abgasen lassen sich VOC-Konzentrationen von <1 – 20 mg/Nm<sup>3</sup> erzielen [217, EC, 2003]. Es werden Kohlenmonoxidkonzentrationen von <100 mg/Nm<sup>3</sup> gemeldet. Im Gegensatz dazu können die NO<sub>x</sub>-Konzentrationen extrem hohe Werte annehmen. So werden Konzentrationen von etwa 1.000 mg/Nm<sup>3</sup> für die katalytische Verbrennung angegeben.

Durch katalytische Verbrennung werden die gesetzlichen Anforderungen in Deutschland größtenteils erfüllt, mit der Verbrennung jedoch werden sie vollständig erfüllt.

Im Vergleich zur Verbrennung erfordert die katalytische Verbrennung eine geringere Betriebstemperatur und es sind keine besonderen Baustoffe erforderlich. Die wahrscheinliche Geruchsbeseitigungsleistung einer katalytischen Nachverbrennungsanlage liegt im Bereich von über 95 %, was geringer als die knapp 100 % ist, die für die thermische Nachverbrennung angegeben werden.

Verbindungen wie Schwefel, Halogene, Zink und organische Feststoffe neigen dazu, die Katalysatoroberfläche zu überziehen. Dieser Prozess ist glücklicherweise reversibel; durch eine hohe Temperatur lässt sich die Katalysatoraktivität wieder herstellen. Auch inertes partikuläres Material führt zu einer allmählichen Abnahme der Katalysatoraktivität, die durch die Einwirkung einer hohen Temperatur von ungefähr 500 °C wieder hergestellt werden kann.

Wenn Staub im Gasstrom vorhanden ist, neigt dieser dazu, sich an der Vorderseite des Katalysators abzusetzen, was zu einer allmählichen Zunahme des Druckverlustes am Katalysator führt. Während Literaturangaben vermuten lassen, dass Konzentrationen von bis zu 115 mg/Nm<sup>3</sup> möglich sind, werden in der Praxis Höchstkonzentrationen von 50 mg/Nm<sup>3</sup> als Richtwert angenommen.

Hinsichtlich der Minimierung von Problemen mit Verschleiß, mechanischer Stabilität, übermäßigem Druckverlust und chemischer Stabilität in der oxidierenden Atmosphäre ist die Honigwabenstruktur effektiver als andere Strukturen.

Die effektive Lebensdauer des Katalysators hängt größtenteils von der Art des behandelten Luftstroms ab. Als Lebensdauer werden stark unterschiedliche Zeiträume in einem Bereich von zwei bis zehn Jahren angegeben, wobei drei bis fünf Jahre normal sein dürften.

Abgase von Räucherammern werden oft mit katalytischer Oxidation bei Temperaturen zwischen 350 und 450 °C behandelt. Wertvolle Metalle (Platin, Palladium) oder bestimmte Metalloxide (Kupfer, Chrom), die auf keramischen Oberflächen abgelagert werden, werden als Katalysatoren genutzt. Sie sind gegenüber Staub, Fettaerosolen und Katalysatorgiften wie Blei und anderen Metallen empfindlich. Die Effizienz wird als hoch angegeben, und Wärme kann rückgewonnen werden.

#### Anwendbarkeit

Eingesetzt zur Verringerung von Emissionen gasförmiger Schadstoffe und Gerüche bei geringen Staubkonzentrationen. Betrieb bei Luftströmen mit verschiedenen Temperaturen und Geruchsfrachten möglich.

#### Wirtschaftliche Aspekte

Geringere Brennstoffkosten im Vergleich zur thermischen Nachverbrennung. Die Austauschkosten für den Katalysator sind mit etwa 50.000 GBP/m<sup>3</sup> (2001) ein wichtiger Parameter für die Berechnung der Betriebskosten.

#### Anlass für die Umsetzung

Einhaltung gesetzlicher Anforderungen zur Geruchsminderung.

#### Beispielanlagen

Werden in Deutschland im Kaffeesektor (siehe Abschnitt 4.7.8.4.3) und in nordeuropäischen Ländern zur Behandlung von Räucherammernabgasen eingesetzt.

#### Referenzliteratur

[34, Willey A R and Williams D A, 2001, 41, Nordic Council of Ministers, 2001, 65, Germany, 2002]

### **4.4.3.12 Nicht-thermische Plasmabehandlung**

#### Beschreibung

Die nicht-thermische Plasmabehandlung ist eine Geruchsminderungstechnik, bei der eine hochreaktive Behandlungszone in den Abgasen erzeugt wird, in der die übelriechenden Moleküle zerstört werden. Diese reaktive Zone kann auf unterschiedliche Art und Weise erzeugt werden.

Plasma ist ein Gaszustand, in dem die Moleküle, aus denen sich das Gas zusammensetzt, in eine Ansammlung von Ionen, Elektronen, ladungsneutralen Gasmolekülen und anderen Teilchen in unterschiedlichen Anregungszuständen aufgeteilt sind. Je nach Menge der zugefügten Energie lässt sich das resultierende Plasma als thermisch oder nicht-thermisch beschreiben.

In thermischem Plasma befinden sich die Plasmabestandteile in einem thermischen Gleichgewicht. Die Ionen und Elektronen haben im Durchschnitt dieselbe Temperatur, die etwa 1 – 2 eV entspricht (wobei 1 eV einer Temperatur von 11.327 °C entspricht). Der Lichtbogen in einem Lichtbogenofen ist ein Beispiel für thermisches Plasma.

In nicht-thermischem Plasma haben die Elektronen ein erheblich höheres Energieniveau bzw. eine erheblich höhere Geschwindigkeit als die Masse der Gasmoleküle. Da nur den Elektronen Energie zugeführt wird, können diese Energien 1 e– 10 eV erreichen, während das Hintergrundgas auf einem der Umgebungstemperatur

entsprechenden Niveau bleibt. Die hohen Elektronenergien erzeugen ein Plasma, in dem gleichzeitig freie Elektronen, Ionen und Radikale vorhanden sind.

Nicht-thermisches Plasma kann zur Behandlung von übelriechenden Abgasen bei Umgebungsdruck und -temperatur verwendet werden. Die Radikale im Plasma reagieren mit den Schadstoffen, die abgebaut und oxidiert werden und somit weniger übelriechende Substanzen bilden. Am aktivsten in diesem Prozess sind Stickstoff-, Sauerstoff- und Hydroxylradikale. Sie entstehen aus Stickstoff, Sauerstoff und Wasser im Abgas.

Industrielle Behandlungssysteme beruhen auf elektrischer Entladung, wobei hohe Spannungen (bis zu 40 kV) verwendet werden, um innerhalb der Abgase Plasma zu erzeugen.

Abbildung 4.38 zeigt den unternehmenseigenen Plan eines industriellen nicht-thermischen Plasma-behandlungssystems.

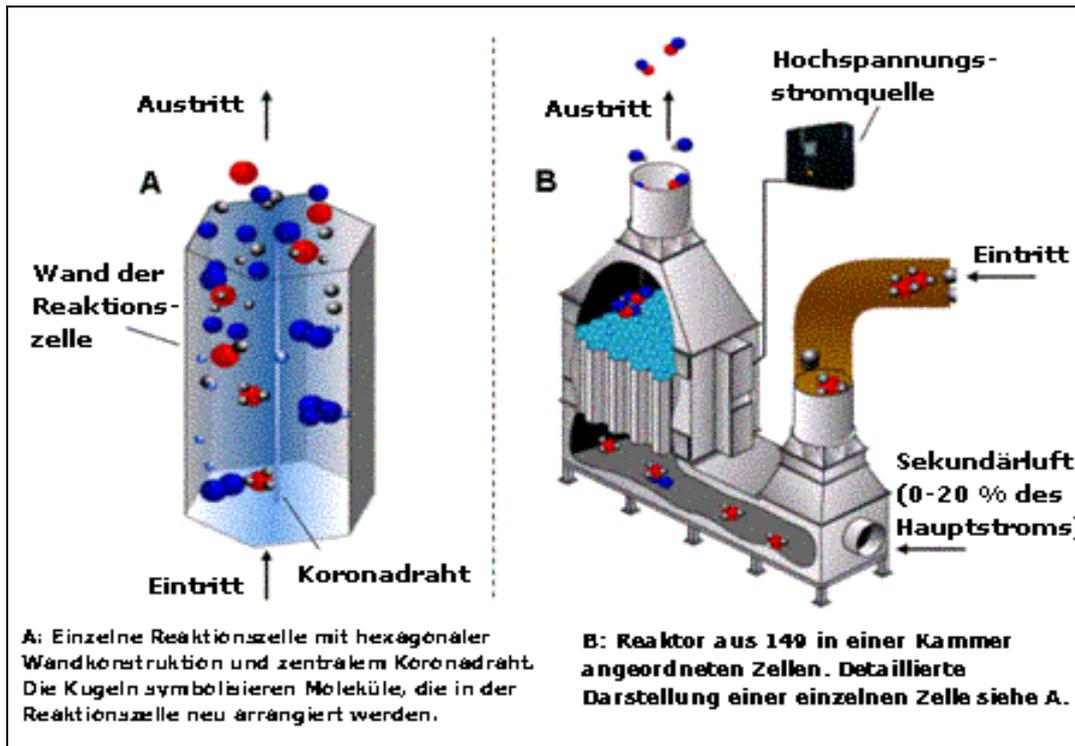


Abbildung 4.38: Industrielle Anlage zur Behandlung mit nicht-thermischem Plasma

Geräte für die Geruchsbehandlung mit nicht-thermischem Plasma verfügen über eine leichte und kompakte Modularbauweise. Mit einem einzelnen Modul wird ein Luftvolumen von 20000 bis 25000 Nm<sup>3</sup>/h behandelt. Werden größere Behandlungskapazitäten benötigt, so können mehrere Module parallel installiert werden. Die Technik erfordert außer Strom für den Betrieb keine Prozesszusätze und kein Verbrauchsmaterial. Sie weist einen geringen Druckverlust im Bereich von 30 – 180 Pa auf. Sie kann sowohl auf der Ansaug- als auch auf der Ausstoßseite des Hauptabzugsgebläses installiert werden.

Erreichbare Umweltvorteile

Verringerte Geruchsemissionen.

Medienübergreifende Auswirkungen

Zur Erzeugung des Plasmas und zur Übertragung von Luft in das Gasgemisch für den Prozess sowie für das Abkühlen und die Wasserkondensation wird Energie benötigt. Es wird Ozon gebildet. Es entsteht Abwasser, das z. B. mit Staub verunreinigt ist.

Betriebsdaten

Die Technik reduziert die Geruchsemissionen nachweislich um 75 – 96 %, je nach Bauart, Prozessbedingungen und Geruchseigenschaften. In Tabelle 4.42 sind die Daten für einige Fischmehl-Beispielanlagen angegeben.

| Branche   | Anzahl von Proben | Geruchsrohgas-konzentration (Mittel) (GE/m <sup>3</sup> ) | Geruchsreingaskonzentration (Mittel) (GE/m <sup>3</sup> ) | Mittel (Bandbreite) der Reduktionseffizienz (%) |
|-----------|-------------------|---|---|---|
| Fischmehl | 3                 | 15.833  | 3.233   | 80 (± 4)  |
| Fischmehl | 3                 | 16.350  | 1.600   | 90 (± 1)  |

**Tabelle 4.42: Geruchsreduktion durch Behandlung mit nicht-thermischem Plasma**

Für den Stromverbrauch werden 6 – 12 kW (1,67 – 3,33 J/h) für ein behandeltes Volumen von 20.000 – 25.000 Nm<sup>3</sup>/h (ein Modul) angegeben. Darin ist der Energieverbrauch der Hochspannungsanlage enthalten, nicht jedoch der erhöhte Energieverbrauch des Hauptabzugsgebläses zum Ausgleich des Druckverlustes (30 – 180 Pa) der Anlage sowie die für etwaige Zusatzluft benötigte Energie. Zusatzluft kann erforderlich sein, um eine ausreichende Konzentration von Radikalen im Gasgemisch aufrechtzuerhalten, und möglicherweise zur Abkühlung der Gase auf die Temperatur, bei der die Technik am effizientesten ist, nämlich zwischen 15 und 80 °C, oder zur Kondensation von Wasser vor der Behandlung. Bis zu 20 % des behandelten Volumens können als Zusatzluft benötigt werden, die normalerweise durch ein speziell dafür vorgesehenes Gebläse bereitgestellt wird.

Im Plasmareaktor wird Ozon gebildet und in die Luft abgegeben. Bei industriellen Anwendungen werden die Ozonkonzentrationen volumenmäßig deutlich unter 1 ppm gehalten, wobei nach der Inbetriebnahme im Allgemeinen keine Überwachung erfolgt. NO<sub>x</sub> und SO<sub>x</sub> werden nicht in nachweisbaren Mengen erzeugt, da anorganische Verbindungen wie NH<sub>3</sub> und H<sub>2</sub>S nicht effektiv vernichtet werden.

Tabelle 4.43 zeigt Daten, die aus verschiedenen Branchen der Nahrungsmittelproduktion gemeldet wurden.

| Land                           | Branche                          | Emissionsquelle                              | Volumenstrom (Nm <sup>3</sup> /h) | Einbau (Jahr) |
|--------------------------------|----------------------------------|--|-----------------------------------|---------------|
| Dänemark                       | Fischmehl                        | Extruder, Trockner, Kühlgeräte               | 22.000                            | 2000          |
| Dänemark                       | Trockenerbsen und Erbsenprodukte | Extruder, Trockner, Kühlgeräte, Hammermühlen | 25.000                            | 2001          |
| Dänemark                       | Proteine                         | Trockner                                     | 25.000                            | 2002          |
| Dänemark                       | Ölextraktion                     | Trockner                                     | 25.000                            | 2002          |
| Dänemark                       | Tierfutter                       | Trockner, Kühlgeräte                         | 50.000                            | 2002          |
| Deutschland                    | Sterilisation von Fischfutter    |  | 6.000                             | 2003          |
| Griechenland                   | Fischmehl                        | Extruder, Trockner, Kühlgeräte               | 44.000                            | 2000          |
| Griechenland                   | Fischfutter                      | Trockner und Kühlgeräte                      | 22.000                            | 2004          |
| Norwegen                       | Fischmehl                        | Extruder, Trockner, Kühlgeräte               | 1.750.000                         | 1998          |
| Norwegen                       | Fischmehl                        | Extruder, Trockner, Kühlgeräte               | 115.000                           | 1998          |
| Norwegen                       | Fischmehl                        | Extruder, Trockner, Kühlgeräte, Hammermühlen | 40.000                            | 2000          |
| Japan                          | Fischfutter                      | Trockner und Kühlgeräte                      | 20.000                            | 2004          |
| Vereinigte Staaten von Amerika | Fischmehl und Tierfutter         | Extruder, Trockner, Kühlgeräte               | 25.000                            | 2002          |

**Tabelle 4.43: Abgasvolumen in Anlagen zur Reduktion von Geruchsemissionen mit Hilfe von nicht-thermischem Plasma**

Wie viele nachgeschaltete Techniken, funktioniert auch diese Technik bei der Behandlung eines hochkonzentrierten Stroms besser als bei der Behandlung geringer Schadstoffkonzentrationen.

Die Bauart der Anlage sowie die gewährten Garantien werden von Feldversuchen zu spezifischen Geruchszusammensetzungen bestimmt. Wenn in der kompletten Anlage wesentlich andere Geruchsmoleküle behandelt werden müssen, weil sich beispielsweise Rohstoffe oder Konzentrationen geändert haben, so kann sich dies auf die Leistung auswirken. Normalerweise werden solche Probleme dadurch gelöst, dass unterschiedliche Systemeinstellungen für die verschiedenen Produkte/Rezepturen automatisch von der zentralen Steuerstelle der Anlage vorgenommen werden.

Angaben zufolge arbeitet die Technik bei bis zu 100 % Luftfeuchtigkeit gut. Von einer Anlage wird gemeldet, dass durch eine Übersättigung des Abgases mit Wasser ( $> 100\%$  Luftfeuchtigkeit) „Regen“ im Reaktor verursacht wurde. Die Wassertröpfchen in der Reaktionskammer führten zu häufigen Funkenübersprüngen in der Reaktionszone, was wiederum eine geringere Elektrizitätsabgabe an den Luftstrom und damit eine geringere Reinigungseffizienz zur Folge hatte. In solchen Situationen kann die Stromeinstellung des Systems reduziert werden, damit Funkenübersprünge auf ein akzeptables Niveau von  $\leq 20$  Funken/Minute begrenzt werden. Im berichteten Fall war die erzielte Reinigungseffizienz noch ausreichend, um die behördlichen Auflagen für die zulässige Gesamtgeruchsemission zu erfüllen, sodass der Kunde das System unverändert akzeptierte. Diese Art von Problemen wird normalerweise gelöst, indem bis zu 20 % kalte Luft zugemischt werden, um die Kondensation zu anzuregen, und ein Tröpfchenfilter vor der Plasmabehandlungseinheit installiert wird. In mehreren Anlagen wurde so verfahren.

Oberhalb von  $80\text{ }^{\circ}\text{C}$  fällt die Leistung der Technik aufgrund der elektrochemischen Eigenschaften des Abgases deutlich ab, sodass als maximale Zufuhrtemperatur  $70\text{ }^{\circ}\text{C}$  angegeben werden. Wärmere Luftströme können durch Beimischung von Luft mit Umgebungstemperatur abgekühlt werden.

Die Anlage wird für die Behandlung eines spezifischen Luftvolumens konstruiert und in modularen Einheiten für etwa  $20.000\text{ m}^3/\text{h}/\text{Modul}$  gebaut. Für größere Volumen können mehrere Module parallel installiert werden. Wenn der tatsächliche Strom sich jedoch deutlich von den Planungsvorgaben unterscheidet, kann sich dies auf die Leistung auswirken.

Zusätzlich zur Geruchsminderung fungiert der Plasmareaktor auch als elektrostatischer Abscheider. Bei staubbefrachteten Luftströmen kommt es daher mit der Zeit zu einer Staubablagerung in der Reaktionskammer und auf dem Koronadraht. Die Geschwindigkeit, mit der sich diese Ablagerung bildet, hängt von der Staubkonzentration und den Staubeigenschaften ab. Die Erfahrung lehrt, dass die Plasmatechnik mit Staubkonzentrationen von  $< 25\text{ mg}/\text{Nm}^3$  gut funktioniert. Unter diesen Umständen kann der Reaktor über mehrere Monate kontinuierlich betrieben werden. Anschließend ist normalerweise eine Reinigung erforderlich. Aus diesem Grund sind viele der industriellen Anwendungen mit einem Nassreinigungssystem ausgestattet, das (halb)automatisch während der Produktionspausen arbeitet und den gesammelten Staub in eine Kläranlage spült. Bei sehr hohen Staubfrachten besteht ein Verstopfungsrisiko für das Gerät, und häufige Reinigungen sind erforderlich. Außerdem führen hohe Staubkonzentrationen im Abgas zu häufigerem Funkenschlag und können daher die Effizienz der Geruchsminderung beeinträchtigen. Normalerweise treten solche hohen Konzentrationen nur bei Ausfällen der vorgeschalteten Entstaubungsgeräte auf.

### Anwendbarkeit

Die Behandlung mit nicht-thermischem Plasma kann als nachgeschaltete Lösung für übelriechende Abgase in der Nahrungsmittelproduktion installiert werden. Dazu zählen z. B. die Emissionen von Extrudern, Trocknern, Kühlgeräten und Hammermühlen. Die Technik wird auf eine Reihe von Abgasarten angewendet, zu denen auch staubhaltige gehören. Allerdings kann eine vorgeschaltete Entstaubung erforderlich sein. Die am stärksten riechenden Abgase enthalten eine Mischung aus organischen und anorganischen Stoffen. Der Plasmaprozess sehr leistungsstark bei organischen Bestandteilen und weniger effizient in der Beseitigung einiger anorganischer Verbindungen wie  $\text{NH}_3$  und  $\text{H}_2\text{S}$ . Das ist darauf zurückzuführen, dass die derzeit verfügbaren Energiedichten nicht stark genug sind, um diese Verbindungen zu zerlegen. Bei dieser Technik muss verhindert werden, dass übermäßige Wassermengen im Gerät kondensieren.

Durch Änderungen in der Abgasleitfähigkeit ist die nicht-thermische Plasmatechnik bei Abgastemperaturen oberhalb  $80\text{ }^{\circ}\text{C}$  weniger effektiv.

Es gibt einige ungeklärte Fragen hinsichtlich der Zuverlässigkeit und Leistung dieser Technik sowie mögliche Sicherheitsbedenken, wenn die Technik zur Behandlung von Luftströmen eingesetzt wird, die eine Brand- und

Explosionsgefahr darstellen. Bei der Abfassung dieses Dokuments war die Bewertung von Anwendung und Leistung der Technik in der Nahrungsmittelproduktion noch abgeschlossen.

#### Wirtschaftliche Aspekte

Nach Angaben des Herstellers der Technik kostet ein Modul (zur Behandlung von 20.000 bis 25.000 Nm<sup>3</sup>/h) etwa 1 Million NOK, was etwa 117.000 EUR entspricht (März 2004). Darin sind die nötigen Geräte, elektromechanischen Dienste und Inbetriebnahme durch den Lieferanten, nicht jedoch die mechanische Installation enthalten. Die jährlichen Wartungskosten betragen etwa 3 – 5 % der Investitionskosten. Verbraucht werden Strom und geringe Mengen an Spülwasser.

#### Beispielanlagen

In der Nahrungsmittelproduktion wird die Technik den Angaben zufolge im Industriemaßstab in mehreren Fischmehlfabriken, bei der Herstellung von Erbsenprodukten, Tierfutter, Proteinen und in der Ölextraktion eingesetzt. Sie wird ebenfalls in mindestens einer Abfallsortieranlage in Dänemark, einer Dungverarbeitungsanlage in Norwegen und einer pharmazeutischen Anlage in Norwegen verwendet. Aufgrund ihres elektrostatischen Reinigungseffekts wird sie in mindestens einer Siliziumkarbidanlage in Norwegen eingesetzt.

#### Referenzliteratur

[146, Leendertse. A., 2003, 193, Leendertse A. and Haaland A.T, 2003]

### **4.4.3.13 Verteilung von Geruchs-/VOC-Emissionen**

Manchmal erfolgt die Verteilung über am Standort vorhandene Einrichtungen, z. B. einen hohen Kessel-schornstein. Gesetzliche Vorgaben zu übelriechenden Emissionen, sofern sie nicht auch als schädlich gelten, beziehen sich auf deren Auswirkungen und nicht auf ihre Entstehung. Das bedeutet, dass sich die Notwendigkeit der Behandlung übelriechender Emissionen aus den Auswirkungen ergibt, die diese nach ihrer Verteilung in der Luft auf die Umgebung haben. Die Kontrolle der Verteilung von Emissionen in die Luft ist üblicherweise sowohl auf die Vermeidung von Beschwerden als auch auf die gesetzlichen Bestimmungen bezüglich Geruchsemissionen und deren Zusammensetzung, z. B. wenn sie VOC enthalten, ausgerichtet.

So können beispielsweise geringere Konzentrationen in Bodennähe erreicht werden, ohne dass die Größenordnung der Geruchsemission verringert wird, wenn einfach deren Ausbreitung in der Luft verbessert wird. Auch die Zugabe eines parfümierten Bestandteils, also eines maskierenden Wirkstoffs, ist eine Möglichkeit der Geruchsbehandlung. Diese Möglichkeit wird jedoch nicht empfohlen.

Die Ausbreitung einer Abluftemission in der Luft und damit die sich ergebende Geruchskonzentration in Bodennähe hängen von einer Vielzahl von Faktoren ab, darunter:

- die vorherrschenden meteorologischen Bedingungen
- die Ableithöhe
- die Position nahegelegener Gebäude und Strukturen
- die Schornsteintemperatur (thermischer Auftrieb)
- die Austrittsgeschwindigkeit am Schornstein
- die Konfiguration des Schornsteins.

Mit Ausnahme der vorherrschenden meteorologischen Bedingungen können alle der oben genannten Faktoren dahingehend geändert werden, dass die Ausbreitung der Emissionen im Radius vergrößert wird. Der Einfluss der obigen Faktoren kann mit einem computerbasierten Ausbreitungsmodell untersucht werden, das diese Faktoren bei der Berechnung der Geruchskonzentrationen in Bodennähe einbezieht. Das Modell erlaubt die quantitative Beurteilung des Einflusses von Schornsteinhöhe oder Austrittsgeschwindigkeit auf die sich ergebenden Konzentrationen in Bodennähe.

Dieser Abschnitt und seine Unterabschnitte beziehen sich auf den Einsatz computerbasierter Ausbreitungsmodelle zur Identifizierung der optimalen Austrittsbedingungen für die Minimierung der Geruchskonzentrationen in Bodennähe. Die Modelle werden in diesem Dokument nicht beschrieben. Es gibt außerdem einfache Berechnungsverfahren, nach denen sich die optimale Schornsteindimensionierung berechnen lässt, ohne dass teure Ausbreitungsmodelle entwickelt werden müssen. Diese einfachen Berechnungsverfahren können als Richtschnur verwendet werden, z. B. um in einer ersten Einschätzung die Frage zu beantworten, ob die

Erhöhung eines Schornsteins oder die Austrittsgeschwindigkeit erforderlich sind. Auch die praktische Durchführbarkeit solcher Veränderungen kann bewertet werden.

### 4.4.3.13.1 Vergrößerung der Ableithöhe des Schornsteins

#### Beschreibung

Gebäude oder Strukturen in der Nähe der Austrittsöffnung eines Schornsteins können oft die Verteilung behindern und in manchen Fällen dazu führen, dass die Abgasfahne unter dem Einfluss der nahegelegenen Strukturen nach unten gezogen wird. Ausbreitungsmodelle können den potenziellen Einfluss solcher Strukturen berücksichtigen.

#### Erreichbare Umweltvorteile

Geringere Wahrnehmung von Geruchsproblemen in der Nähe der Geruchsquelle.

#### Medienübergreifende Auswirkungen

Die Schornsteine beeinträchtigen das äußere Erscheinungsbild der Anlage. Keine Verhinderung oder Minderung von Produktion und Emission der übelriechenden Substanz(en).

#### Betriebsdaten

Dieses Verfahren wird üblicherweise unter Verwendung einer Korrelation durchgeführt, die Höhe, Breite und Länge des Gebäudes berücksichtigt. So wird beispielsweise im von der US-Umweltbehörde EPA validierten „Breeze Computer Model“ eine Korrelation verwendet, die die Höhe und maximale herausragende Breite nahegelegener Gebäude einbezieht. Die maximale herausragende Breite ist definiert als der diagonale Abstand (L) zwischen den äußersten Ecken des Gebäudes an der höchsten Gebäudestelle. Das Verfahren sieht dann vor, um das Gebäude/die Struktur herum einen Kreis mit einem Radius von  $5 \times L$  zu ziehen. Wenn die Ausstoßöffnung des Schornsteins innerhalb von  $5 \times L$  zum/zur nahegelegenen Gebäude/Struktur liegt, ist anzunehmen, dass das Gebäude sich negativ auf die Verteilung vom Schornstein aus auswirken wird. Entsprechend gilt, dass keine Auswirkung auf die Verteilung zu erwarten ist, wenn der Schornsteinausstoß außerhalb des  $5 \times L$ -Radius liegt.

Der Benutzer kann dann mit Hilfe des Verfahrens ermitteln, wie hoch der Schornstein sein muss, damit die Verteilung nicht von dem Gebäude/der Struktur beeinträchtigt wird. Dazu gehört der Vergleich des diagonalen Abstands (L) mit der Gebäude-/Strukturhöhe. Der kleinere der zwei Messwerte wird dann zur Ermittlung der Schornsteinhöhe, die erforderlich ist, damit kein Einfluss durch das Gebäude/die Struktur auftritt, in die folgende Gleichung eingesetzt:

$$h_e = h_b = 1,5 \times L$$

mit

$h_e$  = erforderliche Schornsteinhöhe

$h_b$  = Höhe des Gebäudes bzw. der Struktur

L = diagonaler Abstand

Mit diesem Verfahren kann auf einfache Art festgestellt werden, ob der Ausstoß eines bestehenden Schornsteins dem Einfluss nahegelegener Gebäude/Strukturen ausgesetzt ist. Die Analyse zeigt dann, ob die Erhöhung des Schornsteins eine machbare Lösung darstellen würde. In dieser Hinsicht müssen auch mögliche Bauvorschriften zu Höhenbegrenzungen genauso wie möglicherweise erforderliche Stützstrukturen berücksichtigt werden.

#### Anwendbarkeit

Anwendbar in Anlagen der Nahrungsmittelproduktion mit übelriechenden Emissionen, die nur als störend, aber nicht als schädlich angesehen werden.

#### Wirtschaftliche Aspekte

Die Technik ist mit geringen Kosten verbunden.

#### Referenzliteratur

[34, Willey A R and Williams D A, 2001]

#### 4.4.3.13.2 Erhöhung der Austrittsgeschwindigkeit am Schornstein

##### Beschreibung

Die Größenordnung der Austrittsgeschwindigkeit, mit der die endgültige Emission in die Atmosphäre erfolgt, kann einen wesentlichen Einfluss auf die anschließenden Auswirkungen einer übelriechenden Emission in Bodennähe haben. Eine höhere Austrittsgeschwindigkeit führt dazu, dass die Emission mit mehr Schwung bzw. Auftrieb erfolgt. Das bedeutet, dass der Ausstoß eine größere Höhe erreicht, sich dadurch potenziell stärker in der Luft verteilt und es so zu geringeren Konzentrationen in Bodennähe kommt.

##### Erreichbare Umweltvorteile

Verringerte Geruchsemissionen.

##### Medienübergreifende Auswirkungen

Energieverbrauch.

##### Betriebsdaten

Der übliche Planungsbereich für Austrittsgeschwindigkeiten aus Schornsteinen liegt zwischen 10 und 20 m/s; Branchenstandard sind 15 m/s. Vorgesehene Geschwindigkeiten von weniger als 10 m/s führen wahrscheinlich zu einer schlechten Verteilung, während Geschwindigkeiten von mehr als 20 m/s teuer werden können (Leistung des Abzugsgebläses, Betriebskosten). Außerdem können Austrittsgeschwindigkeiten oberhalb von 20 m/s zu erheblichem Lärm führen, da der Ausstoß ein Pfeifen erzeugt.

Bei manchen Anlagen können auch Einschränkungen für die geplante Geschwindigkeit gelten. In Richtlinien dokumenten wird häufig für den Ausstoß von Nassabscheidungsanlagen wie Wasserwäschern ein Maximalwert von 9 m/s angegeben. Diese Einschränkung soll der Verschleppung erheblicher Mengen von Wassertröpfchen entgegenwirken, die zu einem Springbrunneneffekt führen kann.

Die Austrittsgeschwindigkeit des Schornsteins kann erheblich verringert sein, wenn sich physische Hindernisse im Weg des Ausstoßstroms befinden. Solche Hindernisse verringern den Schwung der Abgasfahne während des Ausstoßes. Viele Schornsteine sind mit einem Kegel über der Austrittsöffnung versehen, der verhindern soll, dass Regen über den Schornstein in den Prozess eindringt. Die austretende Prozessluft wird daher in einem 90°-Winkel nach außen gedrückt, nicht direkt nach oben, sodass der verfügbare Schwung erheblich gedämpft wird. Wenn kein Regenschutz verwendet wird, muss der Schornstein so geplant werden, dass Regen abgefangen wird.

##### Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

##### Wirtschaftliche Aspekte

Die Technik ist mit geringen Kosten verbunden.

##### Referenzliteratur

[34, Willey A R and Williams D A, 2001]

## 4.5 Nachsorgende Abwasserbehandlung (End-of-pipe-Techniken)

Die Behandlung von Abwasser ist eine „nachsorgende“ Behandlung. Dazu zählt Wasser von der Fahrzeug-, Geräte- und Anlagenreinigung sowie vom Waschen von Rohmaterial. Abwasser fällt auch bei der Verdampfung oder beim Trocknen von Nahrungsmitteln an. Kläranlagen verbrauchen Energie und erzeugen Rückstände, die normalerweise entsorgt werden müssen.

Die Abwasserbehandlung erfolgt, nachdem sowohl der Verbrauch als auch die Verunreinigung von Wasser durch „prozessintegrierte“ Arbeitsgänge minimiert wurde.

Kapitel 2 deckt die Prozessarbeitsabläufe in der Nahrungsmittelproduktion ab, beschreibt aber nicht die Arbeitsabläufe der nachsorgenden Behandlungstechniken. In den folgenden Abschnitten werden allgemeine Fragestellungen rund um das Abwasser aus der Nahrungsmittelproduktion und seine Behandlung vorgestellt. Anschließend werden die am häufigsten eingesetzten Behandlungsverfahren einzeln beschrieben, und dann folgen Informationen zur Abwasserbehandlung in verschiedenen Branchen der Nahrungsmittelproduktion.

Mit Techniken, die in der Nahrungsmittelproduktion in vielen Bereichen anwendbar sind, werden Umweltvorteile wie Abfallminimierung erzielt, und es können, bezogen auf einen bestimmten Abwasserstrom, einige oder alle der folgenden Ergebnisse erzielt werden:

- Verringerung des Volumens
- Verringerung der Belastung
- Beseitigung oder Konzentrationssenkung von bestimmten Stoffen
- Verbesserung der Eignung für Wiederverwertung oder Wiederverwendung.

Diese Techniken werden überall in diesem Dokument behandelt. Manche sind überall in der Nahrungsmittelproduktion anwendbar, andere nur bei bestimmten Arbeitsabläufen oder in bestimmten Branchen.

Kapitel 2 deckt die Prozessarbeitsabläufe in der Nahrungsmittelproduktion ab, beschreibt aber nicht die Arbeitsabläufe der nachsorgenden Behandlungstechniken. Dieser Abschnitt behandelt daher die Verminderungstechniken, die zur Abwasserbehandlung in der Nahrungsmittelproduktion eingesetzt werden. Zu diesen Techniken zählen solche, die als BVT in Frage kommen, und andere. In den Abschnitten 4.5.2 bis einschließlich 4.5.6.1.5 werden Techniken beschrieben, die im Allgemeinen in den meisten Branchen Anwendung finden. In den Abschnitten 4.5.7 bis einschließlich 4.5.7.9 wird ihre Anwendung in einigen der einzelnen Branchen beschrieben.

Die Wahl der Abwasserbehandlung wird von vielen Faktoren beeinflusst. Die wichtigsten davon sind:

- Volumen und Zusammensetzung des anfallenden Abwassers
- örtliche Gegebenheiten hinsichtlich der Ableitung des Abwassers, z. B. Kläranlage, Fluss, Flussmündung, See, Meer, und geltende Grenzwerte für Abwassereinleitung
- Wirtschaftlichkeit
- die Entfernung von Schadstoffen, darunter auch gefährliche Substanzen, wie sie in der Richtlinie des Rates 76/464/EWG [206, EC, 1976] definiert sind, und von prioritären gefährlichen Stoffen, wie sie in Richtlinie 2000/60/EG [207, EC, 2000] definiert sind.

### 4.5.1 Abgabe von Abwasser aus Anlagen

Bei der Wahl einer Einleitmöglichkeit sind viele Faktoren zu berücksichtigen, darunter insbesondere:

- ob es sich um sauberes oder kontaminiertes Abwasser handelt
- ob genug Platz für die Behandlung vor Ort verfügbar ist
- ob standortfremde Kläranlagen in der Nähe sind und welche Kapazität sie haben
- ob mögliche Einleitungsgewässer in der Nähe sind und welche Eigenschaften sie haben
- ob andere Behandlungs- oder Entsorgungseinrichtungen außerhalb des Standorts verfügbar sind
- die Kosten für die Behandlung am Standort im Vergleich zu den Kosten für Behandlung/Entsorgung außerhalb
- die relative Effektivität, z. B. anhand der Verringerung der Fracht, von Behandlungen am Standort und außerhalb
- die Bewertung der Umweltrisiken der verschiedenen Möglichkeiten
- die Entsorgung von Sekundärabfällen, die bei der Behandlung am Standort anfallen
- die Möglichkeit zu Betrieb und Wartung von Behandlungseinrichtungen am Standort
- Verhandlungen mit der Genehmigungsbehörde und/oder dem Kläranlagenbetreiber und die zu erwartenden Genehmigungsaufgaben
- voraussichtliche Trends in der Entwicklung von Volumen und Zusammensetzung des Abwassers
- die Nähe zu Anrainern/Anwohnern.

Die wichtigsten Möglichkeiten für die Einleitung von Abwasser einer Anlage sind:

- außerhalb des Betreibers, z. B. an eine kommunale Kläranlage ohne vorherige Behandlung
- außerhalb des Betreibers, z. B. an eine kommunale Kläranlage nach vorheriger Behandlung
- nach vollständiger Behandlung in der betriebseigenen Kläranlage in ein Gewässer

- Wiederverwendung bestimmter Abwasserströme außerhalb des Betreibers, z. B. als Zufuhrstrom in einer anderen Branche oder zur Bewässerung,
- Ausbringung auf Böden außerhalb des Betreibers (siehe Abschnitt 4.1.6).

[13, Environment Agency of England and Wales, 2000]

Wenn ein Betrieb unbedingt in der Nähe der Quelle des von ihm verarbeiteten Rohmaterials sein muss und sich deshalb an einem abgeschiedenen Ort befindet, gibt es unter Umständen keine Alternative zu einer vollständigen Behandlung des Abwassers im Betrieb und der Abgabe an ein örtliches Gewässer. In den meisten Fällen jedoch gibt es zwei oder mehr Möglichkeiten, die ausführlich gegeneinander abgewogen werden sollten. Die Abwasserentsorgung kann ein wesentlicher Faktor bei der Standortentscheidung für neue Betriebe sein.

Für die Behandlung einzelner Abwasserströme am Standort bestehen folgende Vorteile:

- mehr Flexibilität für Produktionssteigerungen und schnelle Reaktion auf veränderte Bedingungen
- Einrichtungen zur Behandlung an der Quelle sind üblicherweise maßgeschneidert und erbringen daher eine gute Leistung
- die Bediener der Produktionseinheiten zeigen einen verantwortungsvolleren Umgang mit der Abwasserbehandlung, wenn sie für die Qualität des von ihnen selbst eingeleiteten Abwassers verantwortlich gemacht werden.

Die Vorteile einer kombinierten Behandlung des Abwassers (am Standort und außerhalb des Betriebes) sind folgende:

- Nutzung von Mischeffekten, z. B. bei Temperatur und pH
- geringere Investitionskosten durch Maßstabeffekte
- effektiverer Gebrauch von Chemikalien und Geräten, wodurch die relativen Betriebskosten sinken
- Verdünnung bestimmter Verunreinigungen, die einzeln nur schwer zu behandeln sind, wie z. B. emulgierte Fette und Sulfate.

Wenn Abwasser in einer Kläranlage außerhalb des Betriebes behandelt wird, gelten die oben genannten Vorteile, wenn folgende Voraussetzungen erfüllt sind:

- die Behandlung in der Kläranlage außerhalb des Betriebes ist genau so gut, wie sie sich in einer innerbetrieblichen Anlage selber erzielen ließe, insbesondere hinsichtlich der Abwasserfracht, es besteht eine geringe Wahrscheinlichkeit, dass die Kläranlage durch Oberflächen-/Notfallüberläufe oder zwischengeschaltete Pumpstationen umgangen wird
- es besteht ein geeignetes Überwachungsprogramm für die Emissionen an die Kläranlage außerhalb des Betriebes im Hinblick auf die mögliche Beeinträchtigung nachfolgender biologischer Prozesse.

[13, Environment Agency of England and Wales, 2000]

Außerdem kann es für die Kläranlage außerhalb des Betriebes vorteilhaft sein, wenn Abwasser aus der Nahrungsmittelproduktion wegen seiner biologisch guten Abbaubarkeit zugegeben wird.

#### 4.5.1.1 Angewendete Techniken der Abwasserbehandlung

Die verschiedenen Abwasserbehandlungstechniken werden in den folgenden Abschnitten in der Reihenfolge beschrieben, in der diese Techniken normalerweise angewandt werden, damit eine immer bessere Qualität des zu reinigenden Abwassers erreicht wird. Durch die Art der verwendeten Rohstoffe und der erzeugten Produkte ist das Abwasser aus Anlagen der Nahrungsmittelproduktion in erster Linie biologisch abbaubar. Allerdings können Reinigungs- und Desinfektionsmittel ein Problem darstellen, wenn sie nur schlecht abbaubar sind. In Tabelle 4.44 sind die beschriebenen Abwasserbehandlungstechniken angegeben und in Tabelle 4.45 ist ihre gebräuchliche Anwendung in der Nahrungsmittelproduktion zusammengefasst.

| Code   | Technik  | Abschnitt                  |
|--|--|----------------------------|
| <b>Primärbehandlungen</b>                    |  |                            |
| T1   | Siebe/Rechen   | siehe Abschnitt 4.5.2.1.   |
| T2   | Fettabscheider zur Abscheidung lipophiler Stoffe und leichter Kohlenwasserstoffe | siehe Abschnitt 4.5.2.2.   |
| T3   | Vergleichmäßigung von Durchfluss und Fracht                                      | siehe Abschnitt 4.5.2.3.   |
| T4   | Neutralisation   | siehe Abschnitt 4.5.2.4.   |
| T5   | Sedimentation  | siehe Abschnitt 4.5.2.5.   |
| T6   | Entspannungsflotation (DAF)  | siehe Abschnitt 4.5.2.6.   |
| T7   | Havariebecken (für Notfälle)   | siehe Abschnitt 4.5.2.7.   |
| T8   | Zentrifugation   | siehe Abschnitt 4.5.2.8.   |
| T9   | Fällung  | siehe Abschnitt 4.5.2.9.   |
| <b>Sekundärbehandlungen</b>                  |  |                            |
| T10  | Belebtschlamm  | siehe Abschnitt 4.5.3.1.1. |
| T11  | Reinsauerstoffsysteme  | siehe Abschnitt 4.5.3.1.2. |
| T12  | SBR  | siehe Abschnitt 4.5.3.1.3. |
| T13  | Aerobe Abwasserteiche  | siehe Abschnitt 4.5.3.1.4. |
| T14  | Tropfkörper  | siehe Abschnitt 4.5.3.1.5. |
| T15  | Turbidologie   | siehe Abschnitt 4.5.3.1.6. |
| T16  | Rotationstauchkörper (RBC)   | siehe Abschnitt 4.5.3.1.7. |
| T17  | Belüftete und geflutete Biofilter – Getauchte und belüftete Biofilter            | siehe Abschnitt 4.5.3.1.8. |
| T18  | Hochleistungsfilter  | siehe Abschnitt 4.5.3.1.9. |
| T19  | Anaerobe Abwasserteiche  | siehe Abschnitt 4.5.3.2.1. |
| T20  | Anaerobe Kontaktverfahren  | siehe Abschnitt 4.5.3.2.2. |
| T21  | Anaerobfilter  | siehe Abschnitt 4.5.3.2.3. |
| T22  | UASB-Reaktoren (anaerobes Schlammkontaktverfahren)                               | siehe Abschnitt 4.5.3.2.4. |
| T23  | Reaktoren mit interner Zirkulation   | siehe Abschnitt 4.5.3.2.5. |
| T24  | Hybrid-UASB-Reaktoren  | siehe Abschnitt 4.5.3.2.6. |
| T25  | Wirbelschicht- und Expanded-Bed-Reaktoren  | siehe Abschnitt 4.5.3.2.7. |
| T26  | EGSB-Reaktoren (Expanded granular sludge bed reactors)                           | siehe Abschnitt 4.5.3.2.8. |
| T27  | Membranbioreaktoren  | siehe Abschnitt 4.5.3.3.1. |
| T28  | Mehrstufige Systeme  | siehe Abschnitt 4.5.3.3.2. |
| <b>Nachsorgende Behandlung des Abwassers</b> |  |                            |
| T29  | Biologische Nitrifikation und Denitrifikation                                    | siehe Abschnitt 4.5.4.1.   |
| T30  | Ammoniakstrippung  | siehe Abschnitt 4.5.4.2.   |
| T31  | Biologische Phosphorentfernung   | siehe Abschnitt 4.5.4.3.   |
| T32  | Entfernung gefährlicher und prioritärer gefährlicher Stoffe                      | siehe Abschnitt 4.5.4.4.   |
| T33  | Filtration   | siehe Abschnitt 4.5.4.5.   |
| T34  | Membranfiltration  | siehe Abschnitt 4.5.4.6.   |
| T35  | Biologische nitrifizierende Filter   | siehe Abschnitt 4.5.4.7.   |
| T36  | Desinfektion und Sterilisation   | siehe Abschnitt 4.5.4.8.   |
| <b>Natürliche Behandlungen</b>               |  |                            |
| T37  | Integrierte, künstlich geschaffene Feuchtgebiete                                 | siehe Abschnitt 4.5.5.1.   |
| <b>Klärschlammbehandlungen</b>               |  |                            |
| T38  | Schlammkonditionierung   | siehe Abschnitt 4.5.6.1.1. |
| T39  | Schlammstabilisierung  | siehe Abschnitt 4.5.6.1.2. |
| T40  | Schlammeindickung  | siehe Abschnitt 4.5.6.1.3. |
| T41  | Schlammwässerung   | siehe Abschnitt 4.5.6.1.4. |
| T42  | Schlamm Trocknung  | siehe Abschnitt 4.5.6.1.5. |

Tabelle 4.44: Beispiele für Abwasserbehandlungstechniken

| Emissionsart                                     | Technik   |
|--|---|
| Gelöste organische Stoffe (BSB/CSB)              | T10, T11, T12, T13, T14, T15, T16, T17, T18, T20, T21, T22, T23, T24, T25, T26, T27, T32, T37 |
| Suspendierte Feststoffe                          | T1, T5, T8, T9, T33, T34, T37   |
| Säuren/Laugen                                    | T3, T4  |
| Lipophile Stoffe (frei)                          | T1, T2, T5, T6 <sup>1</sup> , T8 <sup>1</sup> , T9  |
| Lipophile Stoffe (emulgiert)                     | T10, T12, T13, T14, T19, T20, T21, T28  |
| Stickstoff <sup>2</sup>                          | T10, T11, T12, T13, T14, T15, T16, T29, T30, T35, T37   |
| Phosphor   | T9, T10, T12, T14, T15, T16, T31, T37   |
| Gefährliche und prioritär gefährliche Stoffe     | T5, T9, T10, T14, T32   |
| <sup>1</sup> Durch Chemikalieneinsatz verstärkt  |   |
| <sup>2</sup> Schließt Ammoniakentfernung mit ein |   |

**Tabelle 4.45: Beispiele üblicher Anwendungen von Abwasserbehandlungstechniken in der Nahrungsmittelproduktion [1, CIAA, 2002]**

Abwasser aus der Nahrungsmittelproduktion hat die folgenden typischen Eigenschaften:

- Feststoffe (grob und fein verteilt/suspendiert)
- hoher und niedriger pH-Wert
- freie Speisefette/-öle
- emulgiertes Material, z. B. Speisefett/-öl
- lösliche biologisch abbaubare organische Substanzen, z. B. BSB
- flüchtige Substanzen, z. B. Ammoniak und organische Verbindungen
- pflanzliche Nährstoffe, z. B. Phosphor und/oder Stickstoff
- pathogene Keime, z. B. aus Sanitärwasser
- Schwermetalle
- gelöste, nicht biologisch abbaubare organische Verbindungen.

Nach der Behandlung kann die in Tabelle 4.46 angegebene Wasserqualität erreicht werden. In manchen Branchen sind noch niedrigere Werte erreichbar. Informationen zu einzelnen Branchen finden sich in den Abschnitten 4.5.7 bis einschließlich 4.5.7.9. Aufgrund örtlicher Bedingungen kann es erforderlich sein, dass niedrigere Emissionskonzentrationen erreicht werden.

| Parameter   | Konzentration<br>(mg/l) |
|---|-------------------------|
| BSB <sub>5</sub>  | <25                     |
| CSB   | <125                    |
| Abfiltrierbare Stoffe   | <50                     |
| pH-Wert   | 6 – 9                   |
| Organische Fette und Öle  | <10                     |
| Gesamtstickstoff  | <10                     |
| Gesamtphosphor  | <5                      |
| Koliforme Bakterien   | 400 MPN/100 ml*         |
| MPN = most probable number (statistischer Ausdruck für die Zellzahl in einer Kultur)  |                         |
| * Fleischsektor und Molkereisektor  |                         |
| Für BSB <sub>5</sub> und CSB können bessere Werte erreicht werden. Unter Berücksichtigung der lokalen Bedingungen ist es nicht immer möglich oder kosteneffektiv, die aufgeführten Werte für Gesamtstickstoff und Gesamtphosphor zu erreichen |                         |

**Tabelle 4.46: Übliche Qualität von Abwasser aus der Nahrungsmittelproduktion nach Behandlung [140, World Bank (IBRD), et al., 1998]**

Das in den verschiedenen Branchen anfallende Abwasser kann hinsichtlich Zusammensetzung und Konzentration der Schadstoffe große Unterschiede aufweisen, und zu seiner Behandlung kann eine Vielzahl von Verfahren eingesetzt werden. Tabelle 4.47 enthält eine Zusammenfassung einiger Methoden, die in verschiedenen Branchen Anwendung finden. Zur Behandlung stark verschmutzten Abwassers werden häufig verschiedene Verfahren kombiniert.

|  | Fleisch | Kartoffeln | Obst und Gemüse | Pflanzliche Öle | Molke-rei | Stärke | Süßwaren | Zucker | Brauwirtschaft | Mälzen | Getränke | Brennereien und Schnäpse | Wein und Sekt |
|--|---------|------------|-----------------|-----------------|-----------|--------|----------|--------|----------------|--------|----------|--------------------------|---------------|
| <b>Primärbehandlungen</b>  |         |            |                 |                 |           |        |          |        |                |        |          |                          |               |
| Rechen/Siebe   | ja      | ja         | ja              |                 | ja        | ja     | ja       |        | ja             | ja     | ja       | ja                       | ja            |
| Sedimentation  |         | ja         | ja              |                 | ja        | ja     | ja       | ja     | ja             | ja     | ja       | ja                       |               |
| Entspannungsflotator   | ja      | ja         |                 | ja              | ja        | ja     | ja       |        |                |        | ja       |                          |               |
| Fettabscheidung  | ja      | ja         |                 | ja              | ja        | ja     | ja       |        |                |        | ja       |                          |               |
| Zentrifugation   |         |            |                 | ja              |           | ja     |          |        |                |        |          |                          |               |
| Vergleichmäßigung von Durchfluss und Fracht  | ja      |            | ja              | ja              | ja        | ja     | ja       | ja     | ja             | ja     | ja       |                          | ja            |
| Fällung  |         |            |                 | ja              | ja        | ja     | ja       |        |                | ja     | ja       |                          |               |
| Neutralisation   |         |            | ja              | ja              | ja        | ja     | ja       |        | ja             |        | ja       | ja                       | ja            |
| <b>Sekundärbehandlungen</b>  |         |            |                 |                 |           |        |          |        |                |        |          |                          |               |
| Aerobe Behandlung  | ja      | ja         | ja              | ja              | ja        | ja     | ja       | ja     | ja             | ja     | ja       |                          | ja            |
| Anaerobe Behandlung  | ja      | ja         | ja              | ja              | ja        | ja     | ja       | ja     | ja             | ja     | ja       | ja                       | ja            |
| Belebtschlamm  | ja      | ja         | ja              | ja              | ja        | ja     | ja       | ja     | ja             | ja     | ja       |                          | ja            |
| Belebtschlamm, mehrstufig  | ja      | ja         | ja              | ja              | ja        | ja     |          | ja     |                | ja     | ja       | ja                       |               |
| SBR  | ja*     |            | ja*             | ja              | ja        | ja**   |          | ja     | ja             | ja     | ja       |                          | ja            |
| Tropfkörper  | ja      | ja         | ja              |                 |           | ja***  |          | ja     | ja             | ja     | ja       |                          | ja            |
| Aerobe Abwasserteiche  |         | ja         | ja              |                 | ja        | ja***  |          | ja     | ja             | ja     | ja       | ja                       |               |
| ja = in diesem Sektor eingesetzt * in den Niederlanden verwendet ** anaerobe Chargenreaktoren *** in Verbindung mit anaerober Behandlung |         |            |                 |                 |           |        |          |        |                |        |          |                          |               |

**Tabelle 4.47: Zusammenfassung von Abwasserbehandlungsverfahren in verschiedenen Branchen [65, Germany, 2002]**

## 4.5.2 Primärbehandlungen (Vorbehandlung)

In diesem Dokument werden als **Primärbehandlungen** solche Behandlungen bezeichnet, die andernorts auch als vorläufige Behandlung oder Vorbehandlung bezeichnet werden.

### 4.5.2.1 Rechen/Siebe (T1)

#### Beschreibung

Nachdem Feststoffe mit prozessintegrierten Techniken entfernt und ihr Eintrag in das Abwasser verhindert wurde, z. B. mit Filterkörben/-einsätzen in Bodenabläufen innerhalb der Anlage (siehe Abschnitte 4.1.7.6, 4.3.1 und 4.3.1.1), können weitere Feststoffe mithilfe von Rechen/Sieben aus dem Abwasser entfernt werden. Große Mengen nicht emulgierter lipophiler Stoffe (FOG) können so entfernt werden, wenn diese Rechen/Siebe von technischen und betrieblichen Maßnahmen begleitet wird, die ein Verstopfen verhindern.

Ein Rechen/Sieb ist eine Vorrichtung mit Öffnungen meist einheitlicher Größe, die zum Zurückhalten grober Feststoffe im Abwasser verwendet wird. Das Rechen-/Siebelement besteht aus parallel angeordneten Stangen, Stäben oder Drähten, einem Rost, einem Drahtnetz oder einer perforierten Platte. Die Öffnungen können beliebige Form haben, sind aber meistens rund oder rechteckige Schlitz. Der Spaltabstand der Einrichtungen, die zur Entfernung sehr groben Materials vor einer feineren Siebstufe eingesetzt werden, kann 60 – 20 mm betragen. Wenn in einer Konservenfabrik kleinere Partikel wie Gemüsestückchen und beispielsweise Erbsen oder Bohnen entfernt werden sollen, wird der Spaltabstand im Allgemeinen nicht größer als 5 mm gewählt. Der Spaltabstand in automatischen Sieben/Rechen reicht von 0,5 – 5 mm, wobei Öffnungen zwischen 1 und 3 mm weit verbreitet sind. Kleinere Öffnungen (1 – 1,5 mm) sind den Angaben zufolge weniger<sup>15</sup> verstopfungsanfällig als größere (2 – 3 mm).

Die wichtigsten Rechen-/Siebarten sind statische Rechen (grob oder fein), Vibrationssiebe und Siebtrommeln.

**Statische Siebe/Rechen** können aus senkrechten Stäben oder einer perforierten Platte bestehen. Diese Art von statischem Rechen/Sieb erfordert eine manuelle oder automatische Reinigung.

**Vibrationssiebe** sind nur bei schneller Bewegung effektiv. Sie werden normalerweise für die Primärbehandlung eingesetzt, wo ein Nebenprodukt rückgewonnen werden soll, insbesondere, wenn es sich um Feststoffe mit geringem Feuchtigkeitsgehalt handelt und das Abwasser vorzugsweise kein Fett enthält. Vibrationssiebe arbeiten mit 900 – 1.800 U/min. Ihre Bewegung kann kreisförmig, rechteckig oder quadratisch sein, und die Gesamtbewegungsstrecke kann zwischen 0,8 und 12,8 mm liegen. Geschwindigkeit und Bewegung können der jeweiligen Anwendung entsprechend gewählt werden. Von höchster Bedeutung bei der Auswahl eines passenden feinen Vibrationssiebs ist die richtige Kombination aus Drahtstärke und Anteil der offenen Fläche. Die Kapazität eines Vibrationssiebs beruht auf dem prozentualen Anteil der offenen Fläche des Siebmediums.

**Siebtrommeln** nehmen an einem Ende das Abwasser auf und geben am anderen Ende die Feststoffe ab. Die Flüssigkeit gelangt durch das Sieb nach außen in einen Auffangbehälter, aus dem sie abtransportiert wird. Das Sieb wird normalerweise durch kontinuierliches Besprühen mit externen Sprühdüsen gereinigt, die auf den Bereich gerichtet sind, an dem die Feststoffe abgegeben werden. Diese Siebart ist effektiv bei Abwasserströmen, die einen relativ hohen Feststoffgehalt aufweisen. Mikrosiebe trennen Feststoffpartikel mechanisch mithilfe mikroskopisch feiner Gewebe aus dem Abwasser ab. Der wichtigste Betriebsparameter ist der Druckabfall, und die besten Abscheideergebnisse werden angabegemäß bei 5 bis 10 mbar erreicht.

#### Erreichbare Umweltvorteile

Der Gehalt an suspendierten Feststoffen, lipophilen Stoffen und BSB/CSB wird verringert. Rückgewinnung von Produkten, z. B. Fruchtfleisch, Gemüsebrei im Obst- und Gemüsektor. Weniger Risiko von Geruchsemissionen später in der Kläranlage.

#### Medienübergreifende Auswirkungen

Es kann zu Geruchsemissionen kommen, was z. B. von Art und Größe der ausgesiebten Feststoffe abhängt.

#### Betriebsdaten

Tabelle 4.48 zeigt die geschätzte Verringerung der Verschmutzung im Fischsektor durch Trommeldrahtsiebe an.

<sup>15</sup> Anm. d. UBA-Bearb.: Das Wort "weniger" ist zu bezweifeln.

| Quelle der Verschmutzung  | Reduzierung (%) |
|---------------------------|-----------------|
| Weißfisch-Abwasser        | 10 – 20         |
| Abwasser von fettem Fisch | 30 – 40         |

**Tabelle 4.48: Geschätzte Verringerung der Verschmutzung im Fischsektor durch Trommeldrahtsiebe**

Im Fischsektor wird die Entfernung kleiner Feststoffteile den Angaben zufolge mit einem Filterband und einem Vibrationssieb mit einer Maschenweite von 0,1 mm oder darunter durchgeführt.

Siebe verstopfen oft, was eine häufige Reinigung erforderlich macht. Mit **Bogensieben** können Verstopfungen vermieden werden. Sie bestehen aus einer Zufuhrvorrichtung und einer konkaven Oberfläche und sind während des Betriebs **selbstreinigend**. Keilförmige Profilstäbe sind im rechten Winkel zur Fließrichtung des Wassers angeordnet. Ein relativ gleichförmiges Überlaufen gewährleistet, dass das Sieb sich selbst reinigt. Das Sieb besteht aus mehreren Segmenten, die austauschbar sind. Übliche Abstände sind 0,02 – 2 mm bei Siebflächen von 0,1 – 3,0 m<sup>2</sup> (maximaler Durchsatz 300 m<sup>3</sup>/m<sup>2</sup>/h). Bogensiebe werden im Obst- und Gemüsektor häufig verwendet. Alternativ dazu können mit Selbstreinigungseinrichtungen ausgestattete **Trommelsiebe** verwendet werden. Wenn die Verstopfung durch Fettablagerungen verursacht wird, z. B. im Fleisch-, Molkerei- oder Fischsektor, kann eine regelmäßige Reinigung mit Chemikalien und/oder heißem Wasser durchgeführt werden.

### Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

### Wirtschaftliche Aspekte

Durch das Sieben werden der Bedarf an zusätzlicher Abwasserbehandlung und somit die entsprechenden Kosten gesenkt. Die Menge der anfallenden Schlämme, die zusätzliche Entsorgungskosten verursachen, wird ebenfalls reduziert.

### Anlass für die Umsetzung

Geringere Anforderungen an die Abwasserbehandlung.

### Beispielanlagen

Wird in den Branchen Fleisch, Obst und Gemüse, Fisch, Getränke und pflanzliche Öle eingesetzt.

### Referenzliteratur

[28, Nordic Council of Ministers, 1997, 65, Germany, 2002, 134, AWARENET, 2002]

## **4.5.2.2 Abscheider zur Entfernung lipophiler Stoffe und aufschwimmender Kohlenwasserstoffe (T2)**

### Beschreibung

Wenn lipophile Stoffe nicht vor der aeroben biologischen Behandlung abgeschieden werden, können sie die Funktion der Kläranlage beeinträchtigen, da sie von Bakterien nicht leicht abgebaut werden. Freie lipophile Stoffe können mit einem Fettabscheider vom Wasser abgeschieden werden. Ähnliche Einrichtungen werden zur Abscheidung aufschwimmender Kohlenwasserstoffe verwendet.

Eine Weiterentwicklung des Fettabscheiders stellt der Parallelplattenabscheider dar, bei dem sich in der Abscheidekammer Platten befinden, die in einem Winkel von 45° geneigt sind. Die EU-Standardisierung von Abscheidern für Öle, Fette und leichte Kohlenwasserstoffe ist im Gange (prEN 1825 und prEN 858, Teile 1 und 2).

### Erreichbare Umweltvorteile

Beseitigung von freien lipophilen Stoffen aus dem Abwasser. Das System erfordert normalerweise keinen Chemikalienzusatz, sodass rückgewonnene Fette wiederverwendet werden können.

### Medienübergreifende Auswirkungen

Je nach Art des Fettabscheiders, z. B. ohne kontinuierliche Räumung der Fettschicht, kann es zu Geruchsemissionen insbesondere während des Entleerens kommen.

Durch die Installation von Fettabscheidern in der Produktionsanlage kann es zu Problemen mit der Lebensmittelsicherheit kommen. Zu heißes Wasser kann zum Durchfluss von Fetten sowie zum Schmelzen bereits abgeschiedener Fette führen und ist daher zu vermeiden. Das Material der Prallbleche sowie deren einfache Reinigung sind zu berücksichtigen.

Die Größe der Abscheider ist entscheidend für eine saubere Abtrennung und für die Vermeidung der Gefahr von Auswaschungen bei hohen oder außergewöhnlichen Volumenstrom. Wenn der Zufluss starken Schwankungen unterliegt, können Umleitungen erforderlich sein. Zur Verhinderung von Geruchsproblemen sind eine einfache Entleerung und regelmäßige Wartung äußerst wichtig.

#### Betriebsdaten

Die Abscheideeffizienz hängt von der Wassertemperatur ab und ist bei geringer Wassertemperatur größer. Auch das Vorliegen von Emulgatoren kann die Abscheideeffizienz beeinträchtigen. Den Angaben zufolge kann, bezogen auf den Gehalt an freien Ölen/Fetten, eine Effizienz von 95 % erzielt werden.

Aus dem Sektor der Gewinnung und Verarbeitung pflanzlicher Öle und Fette wird berichtet, dass Parallelplattenabscheider sehr verstopfungsanfällig sind.

#### Anwendbarkeit

Anwendbar in Anlagen der Nahrungsmittelproduktion, in denen das Abwasser tierische und pflanzliche lipophile Stoffe enthält.

#### Wirtschaftliche Aspekte

Die erforderlichen Investitionen werden Berichten zufolge von den Einsparungen bei der Abwasserklärung und Anlagenwartung mehr als ausgeglichen.

#### Anlass für die Umsetzung

Weniger von Fett in Abwasserleitungen und Kläranlagen verursachte Probleme, dafür aber geringere zu behandelnde Schmutzfrachten.

#### Beispielanlagen

Wird im Fleischsektor und bei der Gewinnung und Verarbeitung von pflanzlichen Ölen und Fetten eingesetzt.

#### Referenzliteratur

[65, Germany, 2002, 182, Germany, 2003, 185, CIAA-FEDIOL, 2004, 210, Brechtelsbauer P., ]

### **4.5.2.3 Vergleichmäßigung von Durchfluss und Fracht (T3)**

#### Beschreibung

Misch- und Ausgleichsbecken werden üblicherweise bereitgehalten, um für die üblichen Schwankungen von Abwasseranfall und Zusammensetzung gerüstet zu sein oder um korrigierende Maßnahmen wie die pH-Einstellung oder chemische Konditionierung durchführen zu können. Misch- und Ausgleichseinrichtungen sollten auch dann geprüft werden, wenn Abwasserabfluss und -zusammensetzung den vorgesehenen Parametern der Kläranlage entsprechen.

#### Erreichbare Umweltvorteile

Ermöglicht den Betrieb der nachfolgenden Techniken mit optimaler Effizienz. Nutzt Mischeffekte zum Ausgleich extremer Temperaturen oder pH-Werte.

#### Medienübergreifende Auswirkungen

Zu langer Aufenthalt von Abwasser im Ausgleichsbecken kann zu Säure- und Geruchsbildung führen.

#### Betriebsdaten

Es muss für ausreichende Durchmischung und Belüftung gesorgt werden, um die Schaumbildung an der Oberfläche des Ausgleichsbeckens zu minimieren und um eine ausreichende Konzentration an gelöstem Sauerstoff aufrechtzuerhalten, damit der Inhalt nicht anaerob wird, was zu Säure- und Geruchsbildung führen würde. Dessen ungeachtet wird bei Bedarf eine Vorrichtung zur Schaumbeseitigung installiert. Die Verweildauer in Ausgleichstanks beträgt üblicherweise 6 - 12 Stunden.

### Anwendbarkeit

Breiter Anwendungsbereich der Nahrungsmittelproduktion.

### Wirtschaftliche Aspekte

Den Kosten für die Errichtung und den Betrieb eines Ausgleichsbeckens müssen die Kosteneinsparungen durch den reibungslosen Betrieb des nachgeschalteten Abwasserbehandlungsverfahrens gegenübergestellt werden.

### Anlass für die Umsetzung

Die praktisch homogene Beschickung der nachgeschalteten Reinigungsprozesse.

### Beispielanlagen

Misch- und Ausgleichsbecken werden in den Branchen Fleisch, Obst und Gemüse, Stärke, Molkereiprodukte, Getränke und pflanzliche Öle und Fette eingesetzt.

### Referenzliteratur

[1, CIAA, 2002, 13, Environment Agency of England and Wales, 2000]

## **4.5.2.4 Neutralisation (T4) und Selbstneutralisation**

### Beschreibung

Ziel der Neutralisation ist es, die Abgabe von stark saurem oder basischem Abwasser zu vermeiden. Durch Neutralisation können auch nachfolgende Abwasserbehandlungsverfahren geschützt werden.

Folgende Materialien werden üblicherweise zur Neutralisierung von Abwasser mit niedrigem pH-Wert eingesetzt:

- Kalkstein, Kalksteinaufschlämmungen oder Kalkmilch (gelöschter Kalk,  $\text{Ca}(\text{OH})_2$ )
- Natronlauge ( $\text{NaOH}$ ) oder Natriumcarbonat ( $\text{Na}_2\text{CO}_3$ )
- Ionenaustauscher (kationisch).

Folgende Materialien werden üblicherweise zur Neutralisierung von Abwasser mit hohem pH-Wert eingesetzt:

- Einleitung von  $\text{CO}_2$ , z. B. Rauchgas und Gase aus Fermentationsprozessen
- Schwefelsäure ( $\text{H}_2\text{SO}_4$ ) oder Salzsäure ( $\text{HCl}$ )
- Ionenaustauscher (anionisch).

Von Selbstneutralisation spricht man, wenn in bestimmten Fällen durch die Größe des Misch- und Ausgleichsbeckens und passende unterschiedliche pH-Werte der Abwasserteilströme die Neutralisierung ohne Zugabe von Chemikalien erfolgt. Das kann z. B. in Molkereien der Fall sein, in denen sowohl saure als auch basische Reinigungslösungen verwendet und in das Neutralisationsbecken eingeleitet werden.

### Erreichbare Umweltvorteile

Vermeidung der Auswirkungen sehr sauren oder sehr basischen Abwassers, d. h. Korrosion, Beeinträchtigung biologischer Behandlungen und/oder Minderung der Selbstreinigungsfähigkeit von Seen und Flüssen, sowie möglicherweise Verfahrensprobleme für andere Wassernutzer.

### Medienübergreifende Auswirkungen

Durch die Zugabe von Chemikalien zum Abwasser kann der Gehalt an Feststoffen und gelösten Salzen im behandelten Wasser deutlich ansteigen, und der entstehende Schlamm<sup>16</sup> ist unter Umständen schwer zu entsorgen.

### Betriebsdaten

Angaben zufolge kann die Neutralisierung im Brauereisektor in den Produktionsbereichen oder in zentralen Neutralisationsbecken mit Säure oder Lauge erfolgen. Die Neutralisierung von Prozessabwasser erfordert ein Becken/Tank mit einer hydraulischen Verweilzeit von ungefähr 20 Minuten. Die Mischerkapazität sollte ausreichend sein, um das Becken vollständig durchmischt zu halten. Da in Brauereien sowohl saure als auch basische Reinigungsmittel eingesetzt werden, lässt sich der Einsatz von Chemikalien zur Neutralisation senken, indem die hydraulische Verweilzeit im Neutralisationsbecken verlängert wird. Neutralisationsbecken werden oft

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<sup>16</sup> Anm. d. UBA-Bearb.: Im englischen Text falsch beschrieben!

auch als Misch- und Ausgleichsbecken (siehe Abschnitt 4.5.2.3) verwendet, in denen die hydraulische Verweilzeit dann 3 – 6 Stunden beträgt.

Außerdem findet im Prozessabwasser aus dem Brauereisektor normalerweise eine Teilneutralisierung durch **biologische Umwandlung** statt. Es ist beobachtet worden, dass der pH-Wert in Ausgleichstanks auch ohne Zugabe von Säuren abfallen kann, weil organische Stoffe hydrolysiert werden. Dieser Effekt lässt sich nur schwer steuern, senkt aber den Bedarf an Säurezugabe zu basischem Prozessabwasser. Zur Erzielung einer biologischen Ansäuerung ist eine hydraulische Verweilzeit von 3 – 4 Stunden erforderlich.

#### Anwendbarkeit

Anwendbar in Anlagen mit sehr saurem oder sehr basischem Abwasser.

#### Beispielanlagen

Die Neutralisation findet Anwendung in den Branchen Obst und Gemüse, Molkereiprodukte, Brauereien und Getränke.

#### Referenzliteratur

[9, Verband der Deutschen Milchwirtschaft (German Dairy Association), 1999, 65, Germany, 2002]

### 4.5.2.5 Sedimentation (T5)

#### Beschreibung

Als Sedimentation wird die Abscheidung suspendierter Teilchen, die schwerer als Wasser sind, mittels schwerkraftbedingten Absetzens bezeichnet. Die abgesetzten Feststoffe werden als Schlamm vom Beckenboden oder in regelmäßigen Abständen nach dem Ablassen des Wassers entfernt.

Für die Sedimentation können folgende Einrichtungen verwendet werden:

- rechteckige oder runde Becken, die mit den entsprechenden Räumssystemen (Oberflächenräumer für die Beseitigung von lipophilen Stoffen und Bodenräumer für die Beseitigung von Feststoffen) ausgestattet sind und eine ausreichende Verweilzeit bieten, damit das Absetzen erfolgen kann
- laminare oder röhrenförmige Abscheider, in denen Platten zur Vergrößerung der Abscheidefläche verwendet werden.

#### Erreichbare Umweltvorteile

Verringerung der Konzentrationen von suspendierten Feststoffen und lipophilen Substanzen. Verringerung des Abfallaufkommens; so können z. B. im Stärkebereich Schlämme als Nebenprodukt zur Verwendung als Tierfutter rückgewonnen werden. Die Konzentration sedimentierbarer und aufschwimmender gefährlicher und prioritär gefährlicher Substanzen wird gesenkt.

#### Betriebsdaten

Angaben zufolge können im Fischsektor bis zu 35 % der vorhandenen Feststoffe durch Sedimentieren entzogen werden.

Tabelle 4.49 enthält übliche Leistungsdaten für den Brauereisektor nach der Sedimentation an.

| Ausgangsfracht<br>(m <sup>3</sup> /m <sup>2</sup> /h)                           | Endkonzentration<br>SS<br>(mg/l) |
|---|----------------------------------|
| 0,5 – 1,0   | 20 – 30                          |
| Die akzeptable Fracht hängt von den Sedimentationseigenschaften des Schlamms ab |                                  |

**Tabelle 4.49: Übliche Leistungsdaten im Brauereisektor nach der Sedimentation**

Vor- und Nachteile der Sedimentation sind in Tabelle 4.50 angegeben.

| Vorteile                                   | Nachteile   |
|--|---|
| Einfache Installation, wenig Ausfallgefahr | Rechteckige und runde Becken können viel Platz beanspruchen |
|  | Ungeeignet für fein verteilte Stoffe                        |
|  | Laminare Abscheider sind verstopfungsanfällig (durch Fette) |

**Tabelle 4.50: Vor- und Nachteile der Sedimentation**

Im Zuckersektor enthält das Transportwasser Schlamm, Steine und Pflanzenreste und hat durch beschädigte Zuckerrüben einen hohen CSB. Die Erde erfordert eine Sedimentation. Es wird berichtet, dass große Sedimentationsteiche benutzt werden. Der aus den Absetzteichen entnommene Schlamm kann weiter entwässert werden. Die so erhaltene Flüssigkeit kann über Diffusoren oder als Transportwasser an die Fabrik rückgeführt werden.

Anwendbarkeit

Anwendbar in Anlagen der Nahrungsmittelproduktion, deren Abwasser suspendierte Feststoffe enthält. Die Anwendung der Technik kann durch den Platzbedarf eingeschränkt sein.

Wirtschaftliche Aspekte

Durch hohe Abwasserbehandlungskosten ist es für die meisten Anlagen im Geltungsbereich der IVU-Richtlinie kosteneffektiv, eine Abscheidung von suspendierten Feststoffen vorzunehmen. Im Vergleich zur Entspannungsflotation bedeutet die Sedimentation höhere Investitions-, aber geringere Betriebskosten.

Beispielanlagen

Wird in den Branchen Fleisch, Obst und Gemüse, Stärke, Getränke und pflanzliche Öle und Fette eingesetzt.

Referenzliteratur

[13, Environment Agency of England and Wales, 2000, 65, Germany, 2002, 136, CBMC - The Brewers of Europe, 2002]

**4.5.2.6 Entspannungsflotation (dissolved air flotation, DAF) (T6)**

Beschreibung

Die Abscheidung von Stoffen, die leichter als Wasser sind, z. B. Speiseöle und -fette, kann durch Flotation verbessert werden. In der Nahrungsmittelproduktion wird meistens die Entspannungsflotation angewandt. Diese Technik verkürzt die Verweildauer, ermöglicht aber nicht die Abscheidung emulgierter lipophiler Stoffe aus Wasser und ist daher in der Nahrungsmittelproduktion nur zur Beseitigung freier lipophiler Stoffe weit verbreitet.

Das Grundprinzip der Entspannungsflotation besteht darin, kleine Luftblasen in das Abwasser mit den suspendierten Feststoffen einzuleiten, die flotiert werden sollen. Die feinen Luftblasen haften an den ggf. chemisch konditionierten Partikeln an, sodass diese dann mit ihnen zusammen an die Oberfläche getragen werden.

Die Luft wird unter einem Druck von 300 – 600 kPa (3 bar – 6 bar) in Wasser gelöst. Sie wird normalerweise in einen Rücklaufstrom des behandelten Abwassers eingeleitet, das bereits eine Flotationseinheit durchlaufen hat. Dieser Teilstrom fließt als übersättigtes Luft-Abwasser-Gemisch in ein großes Flotationsbecken, wo durch die Druckentspannung zahlreiche kleine Luftbläschen entstehen. Die suspendierten Teilchen werden angereichert, eingedickt und durch mechanisches Räumen oder durch Absaugen an der Beckenoberfläche entfernt. Chemikalien wie Polymere, Aluminiumsulfat oder Eisenchlorid können zur Verbesserung der Ausflockung und damit der Anhaftung der Bläschen eingesetzt werden. Für die Entspannungsflotation wird eine ähnliche Einrichtung benutzt wie für die Sedimentation (siehe Abschnitt 4.5.2.5).

Erreichbare Umweltvorteile

Die Konzentrationen freier lipophiler Stoffe, von suspendierten Feststoffen, Stickstoff und Phosphor sowie der BSB/CSB werden verringert. Es entsteht weniger Abfall, d. h., die Schlämme sind eventuell als Nebenprodukt rückgewinnbar; z. B. werden sie im Fleischsektor und im Molkereisektor als Tierfutter verwendet. Das System wird aerob gehalten, sodass nur ein geringes Risiko von Geruchsproblemen besteht.

Betriebsdaten

Tabelle 4.51 zeigt die Abscheideeffizienz der Entspannungsflotation in einer Heringsfiletieranlage.

| Parameter   | Reduzierung (%) |
|---|-----------------|
| CSB   | 70 – 75         |
| BSB   | 80*             |
| Gesamtstickstoff  | 45*             |
| Gesamtphosphor  | 70 – 85         |
| Öl  | 85*             |
| Fett  | 98*             |
| * ungefähre Angabe<br>Entspannungsflotation wird eingesetzt, wenn der Gehalt an freien lipophilen Stoffen hoch ist. |                 |

**Tabelle 4.51: Abscheideeffizienz der Entspannungsflotation in einer Heringsfiletieranlage**

Während der Entspannungsflotation können im Druckluftsystem Blockagen auftreten.

Schlämme, die aus einer Entspannungsflotationszelle rückgewonnen werden, weisen üblicherweise einen Trockenfeststoffgehalt von 3 – 4 % auf. Damit die Schlämme verwertet werden können, dürfen entweder keine Koagulations- und Flockungsmittel eingesetzt werden, oder es müssen geeignete Substanzen dafür gewählt werden.

Anwendbarkeit

Breiter Anwendungsbereich der Nahrungsmittelproduktion.

Wirtschaftliche Aspekte

Durch hohe Abwasserbehandlungskosten ist es für die meisten Anlagen im Geltungsbereich der IVU-Richtlinie kosteneffektiv, eine Abscheidung von suspendierten Feststoffen vorzunehmen. Im Vergleich zur Sedimentation bedeutet die Entspannungsflotation geringere Investitions-, aber höhere Betriebskosten.

Anlass für die Umsetzung

Im Vergleich zur Sedimentation wird für die Entspannungsflotation weniger Platz benötigt, die Abscheideeffizienz ist höher, und es können auch kurzfristige Frachtspitzen abgefangen werden.

Beispielanlagen

Wird in den Branchen Fleisch, Fisch, Obst und Gemüse, Molkereiprodukte, Getränke und pflanzliche Öle und Fette eingesetzt.

Referenzliteratur

[13, Environment Agency of England and Wales, 2000, 28, Nordic Council of Ministers, 1997, 65, Germany, 2002]

#### 4.5.2.7 Havariebecken (für Notfälle) (T7)

Beschreibung

Es können Notfallmaßnahmen vorgesehen werden, um zu verhindern, dass unbeabsichtigte störungsbedingte Abflüsse von Produkten die Kläranlage überlasten und/oder den Betrieb der kommunalen Kläranlage durch plötzliche hohe Frachten beeinträchtigen. Es kann ein Havariebecken eingerichtet werden, das üblicherweise 2 bis 3 Stunden lang einen Spitzenabwasseranfall aufnehmen kann. Die Abwasserströme werden vor dem Eintritt in die Kläranlage überwacht, sodass sie im Bedarfsfall automatisch in das Havariebecken abgezweigt werden können. Das Havariebecken ist mit dem Misch- und Ausgleichsbecken (siehe Abschnitt 4.5.2.3) oder einer Primärbehandlungsstufe verbunden, sodass Abwasser mit zu hohen Frachten allmählich in den normalen Abwasserstrom zurückgeführt werden kann. Alternativ dazu kann auch vorgesehen werden, den Inhalt des Umleitbeckens außerhalb der Anlage zu entsorgen. Havariebecken werden auch eingesetzt, wo es kein Trennsystem für Niederschlagswässer gibt und diese in die anlageneigene Kläranlage gelangen können.

Erreichbare Umweltvorteile

Vermeidung unkontrollierter und unbehandelter Einleitung von Abwasser.

### Anwendbarkeit

Breiter Anwendungsbereich der Nahrungsmittelproduktion.

### Beispielanlagen

Wird in den Branchen Fleisch, Molkereiprodukte und Getränke angewendet.

#### 4.5.2.8 Zentrifugation (T8)

##### Beschreibung

Es stehen vier Haupttypen von Zentrifugen zur Verfügung. **Vollmantel- und Trommelzentrifugen** werden zur Entwässerung in Chargenprozessen eingesetzt. Bei der Vollmantelzentrifugation müssen die flüssigen Überstände entweder von der Oberfläche abgezogen werden oder fließen über ein Wehr am oberen Zentrifugenende ab. Bei dem Trommelsystem wird ein perforiertes Sieb benutzt, sodass die flüssige Phase während der Zentrifugation durch das Siebmedium austritt. Die **Tellerzentrifuge** wird hauptsächlich zur Flüssig-Flüssig-Abscheidung eingesetzt. Die **Dekantierzentrifuge** schließlich ist eine Standardtechnik, die zur Abscheidung von Belebtschlamm weit verbreitet ist. Da bei Zentrifugen stärkere Gravitationskräfte wirken, können sie dazu verwendet werden, Teilchen abzuscheiden, die für die Sedimentation zu klein sind.

##### Erreichbare Umweltvorteile

Verringerung der Konzentrationen von suspendierten Feststoffen und lipophilen Substanzen und Senkung von BSB und CSB. Geringere Abfallmengen, z. B. durch Stärkerückgewinnung bei der Kartoffelverarbeitung.

##### Medienübergreifende Auswirkungen

Hoher Energieverbrauch.

##### Betriebsdaten

Tabelle 4.52 zeigt die Abscheideeffizienz für die Zentrifugation in der Heringsindustrie.

| Parameter                                       | Reduzierung (%) |
|---|-----------------|
| CSB – bei stark verunreinigtem Abwasser         | 45              |
| CSB – bei weniger stark verunreinigtem Abwasser | 16 – 25         |
| Suspendierte Feststoffe                         | 80              |

**Tabelle 4.52: Abscheideeffizienz der Zentrifugation in der Heringsindustrie**

##### Anwendbarkeit

In vielen Bereichen der Nahrungsmittelproduktion anwendbar, z. B. zur Eindickung oder Entwässerung von Belebtschlämmen. Der Einsatz von Zentrifugen als Primärbehandlungstechnik ist eher begrenzt.

##### Wirtschaftliche Aspekte

Wartungs- und Energiekosten können beträchtlich sein, weshalb die Technik für Anlagen mit relativ geringen Strömen nicht interessant ist.

##### Beispielanlagen

Wird in den Branchen Fisch, Obst und Gemüse und Getränke angewendet.

##### Referenzliteratur

[1, CIAA, 2002, 3, CIAA, 2001, 28, Nordic Council of Ministers, 1997, 145, Metcalf & Eddy, 1991, 159, CIAA-CEFS, 2003]

#### 4.5.2.9 Fällung (T9)

##### Beschreibung

Wenn sich feste Partikel nicht durch einfache Gravitation abtrennen lassen, z. B. wenn sie zu klein sind, ihre Dichte der von Wasser zu ähnlich ist oder wenn sie Kolloide/Emulsionen bilden, kann die Fällung eingesetzt

werden. Mit dieser Technik werden die im Wasser gelösten Substanzen durch eine chemische Reaktion in unlösliche Partikel umgewandelt. Die Fällung kann auch zur Entfernung von Phosphor eingesetzt werden.

Der Prozess hat drei wesentliche Teile. Der erste Schritt ist die **Koagulation**, die durchgeführt wird, um das kolloidale/emulgierte System zu destabilisieren, indem das Potenzial reduziert wird, das für die Systemstabilität verantwortlich ist. Zu diesem Zweck werden im Allgemeinen anorganische Chemikalien wie Aluminiumsulfat, Eisenchlorid oder Kalk zugesetzt. Der nächste Schritt ist die **Flockung** kleiner Partikel in größere, die dann leicht abgesetzt oder flотиert werden können. Dazu können Polyelektrolyte zugegeben werden, um große Flocken zu erzeugen. Neben der Koagulation-Flockung kommt es zu einer gewissen Fällung von Metallhydroxiden, die Fettpartikel **adsorbieren**. Nach der Fällung werden die Schlämme entweder durch Sedimentation (siehe Abschnitt 4.5.2.5) oder Entspannungsflotation (siehe Abschnitt 4.5.2.6) entfernt.

#### Erreichbare Umweltvorteile

Verringerung der Konzentrationen von suspendierten Feststoffen, lipophilen Substanzen und Phosphor. Wenn im Produktionsprozess gefährliche oder prioritär gefährliche Substanzen benutzt werden, werden deren Konzentrationen im Abwasser gesenkt.

#### Medienübergreifende Auswirkungen

Durch die Zugabe von Chemikalien zum Abwasser kann der Gehalt an Feststoffen/Salzen deutlich ansteigen, und der entstehende Abfall (Schlamm) ist unter Umständen schwer wiederzuverwenden oder zu entsorgen.

#### Betriebsdaten

Es werden Wirkungsgrade für die Phosphoreliminierung zwischen 70 – 90 % für die Fällung gemeldet. Im Molkereisektor wird über einen größeren Schlammanfall für den Fall berichtet, dass zur Entfernung von Phosphor die Phosphatfällung eingesetzt wird. Die Fällung ist Angaben zufolge einfacher zu handhaben als die biologische Entfernung von Phosphor.

Die Entfernung von Phosphor aus dem Abwasser aus der Speiseölraffinerie kann problematisch sein. Im unbehandelten Abwasser liegt Phosphor in anorganischer und in organischer Form vor. Die organischen Phosphorverbindungen reagieren nicht mit den anorganischen Fällungsmitteln. Durch Fällung, z. B. mit Aluminiumsalzen, können nach einem biologischen Abbau der organischen Verbindungen Abgabekonzentrationen von weniger als 4,5 g/t unraffinierten Öls erreicht werden.

Chemische Behandlungsanlagen sind schwierig zu betreiben, da ihre Leistung sehr stark von den sich ändernden Abwassereigenschaften abhängig ist. Deshalb lassen sie sich nur schwer automatisch betreiben und erfordern sehr viel menschliche Arbeitskraft.

Die Wahl der für die Koagulation und Flockung eingesetzten Chemikalien hängt vom beabsichtigten Entsorgungsweg für die Schlämme ab.

Wenn die Fällung gleichzeitig mit einer Belebtschlamm-Abwasserbehandlung eingesetzt wird, verbessert sie Angaben zufolge das Absatzverhalten des Belebtschlammes. Berichten zufolge macht der zusätzliche Phosphor den Belebtschlamm in manchen Fällen wertvoller für die Nutzung in der Landwirtschaft, kann in anderen Fällen jedoch zu Eutrophierungsproblemen führen. In Tabelle 4.53 ist die Phosphoreliminierungsleistung einer simultanen Belebtschlammbehandlung und Fällung in Kläranlagen fünf finnischer Kartoffelstärkeanlagen angegeben.

|  |         |
|--|---------|
| Zufuhr, Gesamt-P (mg/l)                              | 30 – 90 |
| Abgabe, Gesamt-P (mg/l)                              | 1 – 2   |
| Schlammbelastung 0,1 - 0,3 kg BSB/kg*d <sup>17</sup> |         |

**Tabelle 4.53: Phosphoreliminierungsleistung einer gleichzeitigen Belebtschlammbehandlung und Fällung in Kläranlagen im Kartoffelstärkektor**

#### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion, z. B. zur Beseitigung von suspendierten Feststoffen, lipophilen Stoffen und Phosphor. Im Fischsektor wird diese Technik angewendet, wenn der Ölgehalt

<sup>17</sup> Anm. d. Übers.: An dieser Stelle stand im Ausgangstext "m³d".

des Abwassers gering ist. Im Obst- und Gemüsesektor wird die Technik zur Phosphoreliminierung mittels Aluminium- oder Eisensalzen verwendet.

Die Technik kann auch gleichzeitig (simultan) mit einer weitergehenden Abwasserbehandlung, z. B. Belebtschlammverfahren, oder als nachsorgende Behandlung des Abwassers eingesetzt werden.

### Wirtschaftliche Aspekte

Bei Einsatz dieser Technik wird Abfall (Schlamm) erzeugt, dessen Entsorgung teuer ist.

### Beispielanlagen

Wird in den Branchen Fisch, Obst und Gemüse, Getränke und pflanzliche Öle und Fette eingesetzt.

### Referenzliteratur

[65, Germany, 2002, 199, Finland, 2003]

## 4.5.3 Weitergehende Behandlung des Abwassers

Die weitergehenden Behandlungsverfahren des Abwassers zielen prinzipiell auf die Entfernung biologisch abbaubarer organischer Verbindungen und suspendierter Feststoffe mittels biologischer Methoden ab. Mit der Adsorption von Schadstoffen an den erzeugten organischen Schlamm werden auch nicht biologisch abbaubare Stoffe, z. B. Schwermetalle, entfernt. Auch organischer Stickstoff und Phosphor können teilweise aus dem Abwasser entfernt werden. Sekundäre Behandlungsverfahren können allein oder in Kombination mit anderen eingesetzt werden, je nach den Eigenschaften des Abwassers und den Anforderungen, die bei Einleitung eingehalten werden müssen. Wenn die Behandlung als Kombination von in Reihe geschalteten Techniken durchgeführt werden, spricht man von **mehrstufigen Systemen** (siehe Abschnitt 4.5.3.3.2).

Es gibt im Wesentlichen drei Arten metabolischer Verfahren, nämlich aerobe Verfahren, bei denen gelöster Sauerstoff verwendet wird, anaerobe Verfahren ohne Sauerstoffzufuhr und anoxische Verfahren, in denen die biologische Reduktion von Sauerstoffspendern eingesetzt wird [1, CIAA, 2002, 13, Environment Agency of England and Wales, 2000, 65, Germany, 2002]. In diesem Abschnitt werden Techniken beschrieben, bei denen in erster Linie aerobe und anaerobe metabolische Verfahren zur Anwendung kommen.

Die wichtigsten Vor- und Nachteile der anaeroben Abwasserbehandlungsverfahren im Vergleich zu aeroben Verfahren sind in Tabelle 4.54 angegeben.

| Vorteile   | Nachteile   |
|--|---|
| Geringe spezifische Überschuss-Schlammproduktion; geringere Wachstumsraten bedeuten geringeren Bedarf an Makro- und Mikronährstoffen   | Mesophile Bakterien, die am besten bei 20 – 45 °C wachsen, erfordern möglicherweise eine externe Wärmequelle  |
| Geringer Energiebedarf aufgrund fehlender Belüftung  | Geringe Wachstumsrate erfordert gute Zurückhaltung von Biomasse   |
| Im Allgemeinen geringere Investitions- und Betriebskosten pro kg CSB, bedingt durch geringere Schlammproduktion und geringere Durchmischungskosten   | Die Phase der Inbetriebnahme/Akklimatisierung kann lang sein (nicht für Reaktoren mit granulärem Schlamm, z. B. EGSB, die mit dem Schlamm bereits arbeitender Anlagen angeimpft werden) |
| Erzeugt Biogas, das zur Strom- oder Wärmeerzeugung genutzt werden kann   | Anaerobe Systeme sind empfindlicher als aerobe Systeme, was Schwankungen von Temperatur, pH-Wert, Konzentration und Schadstofffrachten angeht   |
| Geringer Platzbedarf   | Manche Bestandteile des behandelten Abwassers können toxisch/korrodiierend sein, z. B. H <sub>2</sub> S   |
| Kann leicht für längere Zeiträume außer Betrieb genommen und in inaktivem Zustand gehalten werden (nützlich bei saisonalen Herstellungsprozessen, z. B. bei der Verarbeitung von Zuckerrüben).   |   |
| Ein besonderer Vorteil des Verfahrens ist die Pelletbildung. Dadurch ist nicht nur die schnelle Reaktivierung nach monatelangen Betriebspausen möglich, sondern auch der Verkauf von überschüssigen Schlammpellets, z. B. zur Animpfung neuer Systeme. |   |
| Manche Substanzen, die aerob nicht abbaubar sind, können anaerob abgebaut werden, z. B. Pektin und Betain.   |   |
| Weniger Geruchsprobleme, wenn entsprechende Vermeidungstechniken eingesetzt werden.  |   |
| Keine Aerosolbildung, kann lipophile Stoffe assimilieren (nicht bei UASB).   |   |

**Tabelle 4.54: Vor- und Nachteile anaerober Abwasserbehandlungen im Vergleich zu aeroben Verfahren [1, CIAA, 2002, 13, Environment Agency of England and Wales, 2000, 65, Germany, 2002]**

#### 4.5.3.1 Aerobe Verfahren

Aerobe Prozesse sind nur dann allgemein anwendbar und kosteneffektiv, wenn das Abwasser leicht biologisch abbaubar ist. Die Mikroorganismen im Schlamm-/Wassergemisch können ihren Sauerstoff entweder über die Oberfläche oder aus ins Abwasser getauchten Belüftern beziehen. Der Oberflächeneintrag von Sauerstoff erfolgt entweder durch Oberflächenbelüfter oder Oxygenierungskäfige<sup>18</sup>.

Die Vor- und Nachteile aerober Abwasserbehandlungsverfahren sind in Tabelle 4.55 angegeben.

<sup>18</sup> Anm. d. UBA-Bearb.: Der Ausdruck ist im deutschen Sprachgebrauch unbekannt.

| Vorteile                            | Nachteile   |
|-------------------------------------|---|
| Abbau zu unschädlichen Verbindungen | Es fallen große Mengen an Schlamm an  |
|                                     | Bei der Strippung kommt es zu Freisetzungen leicht flüchtiger Stoffe, die Gerüche/Aerosole erzeugen können  |
|                                     | Geringere Bakterienaktivität bei niedrigen Temperaturen Durch Oberflächenbelüftung und Eintrag von reinem Sauerstoff kann der Prozess jedoch beschleunigt werden  |
|                                     | Wenn lipophile Stoffe nicht vor der aeroben biologischen Behandlung ausreichend entfernt werden, können sie die Funktion der Kläranlage beeinträchtigen, da sie von Bakterien nicht leicht abgebaut werden. |

**Tabelle 4.55: Vor- und Nachteile aerober Behandlungsverfahren**  
 [1, CIAA, 2002, 13, Environment Agency of England and Wales, 2000, 65, Germany, 2002]

**4.5.3.1.1 Belebtschlamm (T10)**

Beschreibung

Mit der Belebtschlammtechnik wird eine aktivierte Masse von Mikroorganismen erzeugt, die zum aeroben Abbau von Abwasserinhaltsstoffen in der Lage sind. Die Biomasse wird belüftet und in einem Reaktor in Suspension gehalten. Dazu kann Luft, Sauerstoff oder eine Kombination aus beiden verwendet werden. Wenn Sauerstoff benutzt wird, werden sie als Reinstsauerstoffsysteme bezeichnet (siehe Abschnitt 4.5.3.1.2).

Erreichbare Umweltvorteile

Weniger BSB/CSB, geringere Phosphor- und Stickstoffkonzentration. Wenn im Produktionsprozess gefährliche oder prioritär gefährliche Substanzen benutzt werden, werden deren Konzentrationen im Abwasser gesenkt.

Medienübergreifende Auswirkungen

Hoher Energieverbrauch.

Betriebsdaten

Nach einer vorgegebenen Verweildauer, die von mehreren Stunden bis zu mehr als 10 Tagen reichen kann, je nach organischer Fracht oder spezifischer Schlammbelastung von etwa 0,1 – 0,15 kg BSB/kg TS pro Tag, wird das Abwasser-/Schlammgemisch in eine Sedimentationseinrichtung weitergeleitet (siehe Abschnitt 4.5.2.5). Die hydraulische Verweilzeit oder das Schlammalter und die spezifische Schlammbelastung können alle in Abhängigkeit von den Eigenschaften des Roh-Abwassers, also seiner Zusammensetzung, Verfügbarkeit und Abbaubarkeit organischer Substanzen, schwanken, und sind auch von der erforderlichen Ablaufqualität des Abwassers abhängig. So erfolgt beispielsweise die Nitrifikation bei geringerer spezifischer Schlammbelastung (<0,1 kg BSB<sub>5</sub>/kg TS pro Tag). In der Sedimentationseinheit setzen sich die mikrobiellen Flocken ab und das klare Abwasser wird über ein Wehr in das Gewässer abgeleitet. Es entsteht abgesetzter Schlamm, der zum größten Teil in das Belüftungsbecken rückgeführt wird. Ein Teil davon jedoch, also der überschüssige Schlamm (Überschuss-Schlamm), wird als Abfall entsorgt, damit die TS-Konzentration im Belebungsbecken angemessen bleibt, z. B. bei 3.000 mg/l.

In Tabelle 4.56 sind die Leistungsdaten einer Belebtschlammkläranlage im Brauereisektor angegeben.

|   |             |
|---|-------------|
| <b>Zulauffracht (kg CSB/m<sup>3</sup> pro Tag)</b>  | 1,2 – 1,8   |
| <b>End-BSB<sub>5</sub> (mg/l)</b>   | 15 – 25     |
| <b>Pro entferntem kg BSB<sub>5</sub> erzeugter Schlamm (kg/kg)</b>                        | 0,45 – 0,55 |
| Diese Leistungsdaten gelten im Temperaturbereich von 25 – 35 °C und daher nicht im Winter |             |

**Tabelle 4.56: Leistungsdaten einer Belebtschlammkläranlage im Brauereisektor**

Es werden Phosphoreliminierungsraten zwischen 10 und 25 % für Belebtschlamm gemeldet.

Im Zuckersektor verringern die geringen Luft- und Wassertemperaturen im Winter den Angaben zufolge die Behandlungskapazität, da die bakterielle Aktivität zurückgeht. Es kann jedoch in der Regel Abwärme aus dem Zuckerprozess zur Erhöhung der Systemtemperatur verwendet und so die bakterielle Aktivität gesteigert werden.

Das häufigste Problem im Zusammenhang mit Belebtschlamm ist die Blähschlamm-Bildung. Als Blähschlamm wird biologischer Schlamm bezeichnet, der schlechte Absetzeigenschaften aufweist. Dies ist meist auf das Vorhandensein von Fadenbakterien und/oder übermäßigen, in den biologischen Flocken gebundenen Wassermengen zurückzuführen. Was Blähschlamm betrifft, so gilt, dass Vorbeugen besser ist als nachträgliche Abhilfe. Angaben zufolge besteht eine übliche Abhilfemaßnahme für Blähschlamm im Einsatz von Chemikalien, also einer Chlorierung oder dem Einsatz anderer oxidierender oder fällender Chemikalien, um die fädigen Organismen abzutöten, die nicht durch Belebtschlammflocken geschützt sind. Diese Behandlungsmethoden werden als nicht sehr selektiv angegeben und können die gesamte biologische Aktivität vernichten.

Die Blähschlamm-Bildung lässt sich verhindern, z. B. indem das Nährstoffverhältnis (C/P/N) optimal ausgewogen ist, sodass sowohl die Nährstoffeinleitung als auch die Überproduktion von Fadenbakterien minimiert wird. Zu den Verfahren der Blähschlammvermeidung zählt auch die Verringerung der Fracht. Das Vorhandensein von Ammoniak als Abbauprodukt zeigt an, ob eine Denitrifikation erforderlich ist. Die hydraulische Verweilzeit, das Schlammalter und die Betriebstemperatur sind die wichtigsten zu beachtenden Parameter. Diese müssen auch den Abbau der resistenteren organischen Substanzen berücksichtigen.

Außerdem hat sich der Einsatz eines gesonderten Beckens oder eines Selektors als geeignetes Instrument zur Verhinderung und Begrenzung fädiger Mikroorganismen erwiesen. Dabei handelt es sich um eine Kontaktzone am Kopf der Belebungsanlage, in der das vorbehandelte Abwasser und der rückgeführte Schlamm zusammengeführt werden. Der Selektor bewirkt das selektive Wachstum flockenbildender Organismen durch eine hohe spezifische Schlammbelastung bei einer geregelten Konzentration gelösten Sauerstoffs. Die Kontaktzeit ist kurz, im Allgemeinen 10 – 30 Minuten. Der anoxische Selektor, für den Nitrat im Wasser vorhanden sein muss, ist oft das Mittel der Wahl für Belebtschlamm-Systeme, die nitrifizieren. Zusätzlich zu einer effektiven Vermeidung von Fadenbakterien haben anoxische Selektoren noch den Vorteil, den Sauerstoffbedarf des Prozesses zu senken, weil Nitrat-Stickstoff als Elektronenakzeptor für die Oxidation des zufließenden biologisch abbaubaren Materials genutzt wird. Außerdem wird der Alkalinitätsverbrauch bei der Nitrifikation gesenkt, weil in der anoxischen Zone die Alkalinität wiederhergestellt wird. Anoxische Selektoren können auch sehr effektiv bei der Vermeidung filamentösen Wachstums von Fadenbakterien sein, weil sie sowohl kinetische als auch metabolische Selektionsmechanismen nutzen.

Aus dem Molkereisektor wird die Blähschlamm-Bildung in Belebtschlamm-Systemen bei schwankenden Frachten und geringen spezifischen Schlammbelastungen gemeldet. Der Mangel an Stickstoff und Phosphor bzw. Sauerstoff begünstigt die Blähschlamm-Bildung. Gleiches wird von Ammoniumstoßbelastungen und erhöhtem bzw. angefaultem Abwasser berichtet.<sup>19</sup> Wenn kein Selektor verwendet wird, muss die Sedimentationseinrichtung unter Berücksichtigung dieser schlechteren Absetzeigenschaften des Schlamms entsprechend groß dimensioniert bzw. Filtereinheiten vorgesehen werden.

#### Anwendbarkeit

Breiter Anwendungsbereich in der Nahrungsmittelproduktion. Die Technik kann zur Behandlung von Abwasser mit hohem oder niedrigem BSB eingesetzt werden, ist aber insbesondere bei Abwasser mit geringem BSB sehr effizient und kostengünstig. Die Anwendung der Technik kann durch den Platzbedarf eingeschränkt sein.

#### Wirtschaftliche Aspekte

Die Belebtschlamm-Technik ermöglicht eine kostengünstige Behandlung löslicher organischer Stoffe. Dessen ungeachtet ist es besser, wenn das Abwasser aus dem Stärkesektor, dessen CSB oberhalb von 10.000 mg/l liegt, nicht nur einer aeroben Behandlung unterzogen wird.

In der Getränkeindustrie ist aufgrund der jahreszeitlichen Unterschiede im Abwasser die Belebtschlamm-Technik meist überdimensioniert, was zu entsprechend hohen Investitions- und Betriebskosten führt.

<sup>19</sup> Anm. d. UBA-Bearb., weil der Originaltext die Gegebenheiten nicht genau wiedergibt.

### Beispielanlagen

Wird in den Branchen Fleisch, Fisch, Obst und Gemüse, Stärke, Molkereiprodukte, Brauwirtschaft, Zucker, Getränke und pflanzliche Öle und Fette eingesetzt.

### Referenzliteratur

[65, Germany, 2002, 136, CBMC - The Brewers of Europe, 2002, 145, Metcalf & Eddy, 1991, 199, Finland, 2003]

#### **4.5.3.1.2 Reinsauerstoffsysteme (T11)**

##### Beschreibung

Reinsauerstoffsysteme stellen im Wesentlichen eine Intensivierung des Belebtschlammprozesses dar, also den Einsatz von reinem Sauerstoff in einer bestehenden herkömmlichen Belebungsanlage. Die Umstellung auf Sauerstoffbegasung erfolgt oft, wenn die Effektivität der Belebungsanlage teilweise durch eine erhöhte oder schwankende Belastung gestört wurde.

##### Erreichbare Umweltvorteile

Verringerung von BSB/CSB und der Stickstoffkonzentration. Weniger Geruchspotenzial, da die Oberfläche des Belebungsbeckens im Wesentlichen ungestört bleibt. Geringerer Energieverbrauch.

##### Betriebsdaten

Im Vergleich zu herkömmlichen Belebtschlammverfahren können Reinsauerstoffsysteme den Prozess intensivieren, da sie mit höheren Belebtschlamm-Konzentrationen arbeiten. Außerdem verbraucht diese Technik weniger Energie, da im herkömmlichen Belebtschlammverfahren 70 % der Energie verschwendet werden, weil Stickstoff 70 % des eingeblasenen Luftvolumens einnimmt.

##### Anwendbarkeit

Breiter Anwendungsbereich in der Nahrungsmittelproduktion. Sowohl neue als auch bestehende Anlagen der Nahrungsmittelproduktion sind mit Reinsauerstoffsystemen ausgerüstet worden.

##### Wirtschaftliche Aspekte

Da das System mit extrem hohem Schlammalter arbeitet und die endogene Atmung fördert, durch die sich Biomasse selbst abbaut, somit weniger Überschuss-Schlamm entsteht, reduzieren sich die Entsorgungskosten für den Schlamm erheblich. Dessen ungeachtet sind die Betriebskosten für Anlagen, die Sauerstoff statt Luft verwenden, höher.

##### Anlass für die Umsetzung

Durch den Einsatz reinen Sauerstoffs lässt sich der Prozess besser steuern, die Leistung steigt, und die Technik kann bei bestehenden Anlagen nachgerüstet werden.

### Beispielanlagen

Wird in den Branchen für Fleisch, Obst und Gemüse, Molkereien und Zucker eingesetzt.

### Referenzliteratur

[13, Environment Agency of England and Wales, 2000]

#### **4.5.3.1.3 SBR-Anlagen (Sequencing Batch Reactors) (T12)**

##### Beschreibung

Die SBR-Anlage stellt eine Variante des Belebtschlammverfahrens dar. Sie wird nicht kontinuierlich beschickt, sondern nach dem Befüllungs- und Entnahmeprinzip betrieben und besteht üblicherweise aus mindestens zwei gleichen Reaktionsbecken. Die verschiedenen Stadien des Belebtschlammverfahrens werden alle in demselben Reaktor durchgeführt.

##### Erreichbare Umweltvorteile

Weniger BSB/CSB, geringere Phosphor- und Stickstoffkonzentration.

##### Betriebsdaten

Der Prozess ist sehr flexibel, da innerhalb des Betriebszyklus eine Reihe von Optimierungen vorgenommen werden können, z. B. eine verbesserte Denitrifikation in der Ruhephase. Ein normaler Gesamtzyklus dauert

etwa sechs Stunden. Die Zeit, die für die einzelnen Stufen des Prozesses aufgewendet wird, kann an die örtlichen Gegebenheiten angepasst werden. Außerdem ist die Prozessabfolge unabhängig von Einflüssen durch Schwankungen im hydraulischen Zufluss. In diesem Sinn ist die SBR-Anlage einfacher und robuster zu betreiben als ein herkömmliches Belebtschlammssystem.

Da die Befüllung in Chargen zur Bildung eines leicht absetzbaren Belebtschlammes führt, ist dieser Prozess für industrielle Abwässer mit Neigung zur Blähschlamm-Bildung geeignet.

In Tabelle 4.57 ist der normale Betrieb einer normalen SBR-Anlage dargestellt.

| Schritt   | Zweck                                  | Betrieb (Belüftung) | Maximalvolumen (%) | Zykluszeit (%) |
|---|--|---------------------|--------------------|----------------|
| Befüllen  | Zugabe von Substrat                    | Luft ein/aus        | 25 – 100           | 25             |
| Reaktion  | Biologischer Abbau                     | Luft ein/Zyklus     | 100                | 35             |
| Absetzen  | Trennen von Belebtschlamm und Abwasser | Luft aus            | 100                | 20             |
| Abziehen  | Entfernen von Abwasser                 | Luft aus            | 35 – 100           | 15             |
| Ruhe*   | Abzug des Schlammes                    | Luft ein/aus        | 25 – 35            | 5              |
| * Überschuss-Schlamm kann auch in anderen Schritten auftreten. In Mehrbeckensystemen wird die Ruhephase zum Auffüllen des zweiten Beckens genutzt. Dieser Schritt kann wegfallen. |  |                     |                    |                |

**Tabelle 4.57: Betrieb einer normalen SBR-Anlage**

#### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion. Die Anwendung der Technik kann durch den Platzbedarf eingeschränkt sein. Die Technik kann zur Behandlung von Abwasser mit hohem oder niedrigem BSB eingesetzt werden, ist aber insbesondere bei Wasser mit geringem BSB sehr effizient und kostengünstig.

#### Wirtschaftliche Aspekte

Geringere Investitions- und höhere Betriebskosten als bei herkömmlichen Belebtschlamm-Anlagen.

#### Beispielanlagen

Wird in den Branchen Fleisch, Obst und Gemüse, Molkereiprodukte, Getränke und pflanzliche Öle und Fette eingesetzt.

#### Referenzliteratur

[1, CIAA, 2002, 65, Germany, 2002, 145, Metcalf & Eddy, 1991]

#### **4.5.3.1.4 Aerobe Abwasserteiche (T13)**

##### Beschreibung

Aerobe Abwasserteiche sind große flache Erdbecken, die zur Behandlung von Abwasser durch natürliche Prozesse benutzt werden. Dazu gehört die natürliche Nutzung von Algen, Bakterien, Sonne und Wind. Neben dem von den Algen produzierten Sauerstoff gelangt durch atmosphärische Diffusion zusätzlicher Sauerstoff in die Flüssigkeit. Der Inhalt der Abwasserteiche wird normalerweise regelmäßig durch Einsatz von Pumpen oder Oberflächenbelüftern durchmischt.

Eine Variante des aeroben Abwasserteichs ist der fakultative Abwasserteich<sup>20</sup>, in dem eine Stabilisierung durch eine Kombination aerober, anoxischer oder anaerober Bakterien erzielt wird. In der oberen Schicht eines fakultativen Abwasserteichs kann die Sauerstoffversorgung durch Oberflächenbelüfter aufrechterhalten werden<sup>21</sup>.

##### Erreichbare Umweltvorteile

Weniger BSB und geringere Stickstoffkonzentration.

##### Medienübergreifende Auswirkungen

Potenzielle Geruchsbelästigung, Bodenverschlechterung und Grundwasserkontamination.

<sup>20</sup> Anm. d. UBA-Bearb.: Je nach Bedarf betriebener Abwasserteich in abwassertechnischem Bezug.

<sup>21</sup> Anm. d. UBA-Bearb.: In Deutschland wird die zusätzliche Belüftung meist bei Geruchsbelästigung eingesetzt.

### Betriebsdaten

Angaben zufolge bieten Abwasserteiche durch große Flächen und Volumen Pufferkapazität, dienen bei saisonalem Betrieb dem Volumen- und Konzentrationsausgleich, und durch die sehr langen Verweilzeiten etablieren sich in ihnen angepasste Biozönosen. Je nach den Bodeneigenschaften müssen Abwasserteiche möglicherweise z. B. mit Folien abgedichtet werden, damit das Grundwasser nicht kontaminiert wird.

Für die Zuckerbranche wird angegeben, dass Oberflächengröße und Tiefe entscheidend für den Umfang der BSB-Verringerung sind. Die BSB-Verringerung ist von natürlichen Prozessen wie dem Kohlenstoff-, Stickstoff- und Schwefelkreislauf sowie von Bakterientätigkeit abhängig. Außerdem wird in dieser Branche die aerobe Bakterienaktivität durch Oberflächenbelüftung nach Bedarf gefördert, z. B. bei niedrigen Temperaturen. Zusätzlicher Sauerstoff wird mittels elektrisch betriebener, „freier“ oder „fester“ schwimmender Belüfter in das Wasser eingebracht. Wo die Witterungsbedingungen es erlauben, werden gelegentlich auch windbetriebene Belüfter verwendet<sup>22</sup>. Es gibt auch Mischsysteme für Elektro- und Windantrieb.

Für Weinkellereien und Olivenölmühlen wird über den Einsatz von Verdunstungsteichen berichtet, in denen das Abwasser über Monate hinweg verdunstet<sup>23</sup>.

### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion. Die Anwendung der Technik kann durch den Platzbedarf eingeschränkt sein. Die Technik kann zur Behandlung von Abwasser mit hohem oder niedrigem BSB eingesetzt werden, ist aber insbesondere bei Wasser mit geringem BSB sehr effizient und kostengünstig.

Im Obst- und Gemüsesektor werden Abwasserteiche benutzt, wenn ihr Fassungsvermögen so groß ist, dass kein unkontrolliertes Überlaufen droht und in Zeiten hoher Zuflüsse die Ableitung von Abwasser kontrolliert erfolgen kann.

### Beispielanlagen

Abwasserteiche sind in den Branchen Zucker, Obst und Gemüse, Getränke und pflanzliche Öle und Fette weit verbreitet.

### Referenzliteratur

[65, Germany, 2002, 159, CIAA-CEFS, 2003, 199, Finland, 2003]

#### **4.5.3.1.5 Tropfkörper (T14)**

### Beschreibung

Bei aeroben Festfilmverfahren wie Tropfkörpern wächst die Biomasse als Film auf der Oberfläche des Füllmaterials und das Abwasser wird so verteilt, dass es gleichmäßig darüber fließt.

Das Tropfkörperfüllmaterial besteht normalerweise aus Steinen oder verschiedenen Kunststoffarten. Die behandelte Flüssigkeit wird aufgefangen und in ein Absetzbecken weitergeleitet, von wo ein Teil des Abwassers rückgeführt und zur Verdünnung des zufließenden Abwassers benutzt werden kann. Zu den verschiedenen Möglichkeiten zählen eine abwechselnde Doppelfiltration und die permanente Doppelfiltration.

### Erreichbare Umweltvorteile

Weniger BSB/CSB, geringere Phosphor- und Stickstoffkonzentration. Wenn im Produktionsprozess gefährliche oder prioritär gefährliche Substanzen benutzt werden, werden deren Konzentrationen im Abwasser gesenkt.

### Medienübergreifende Auswirkungen

Potenzielle Geruchsbelästigung.

### Betriebsdaten

Für den Molkereisektor wird angegeben, dass hochbelastete Tropfkörper üblicherweise für die Beseitigung von 50 – 60 % des BSB konzipiert sind. Für den effizienten Betrieb muss unbedingt der Gehalt an lipophilen Stoffen vor der Zufuhr zum Tropfkörper minimiert werden. Nach diesem Verfahrensschritt kann eine Schlamm-sedimentation erforderlich sein, je nachdem, welche Auflagen für die Einleitung gelten. Im Getränkesektor wird

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<sup>22</sup> Anm. d. UBA-Bearb.: In Deutschland ist dieser Betriebsweise nicht bekannt.

<sup>23</sup> Anm. d. UBA-Bearb.: In Deutschland nicht gestattet. Auch in Spanien wird diese Verfahrensweise nicht mehr gestattet.

für diese Technik eine Effizienz von 70 % angegeben, sodass meistens ein weiterer Behandlungsschritt erforderlich ist.

Für Tropfkörper wird die Phosphoreliminierungsrate mit 8 – 12 % angegeben.

#### Anwendbarkeit

Anwendbar des schwach belasteten Tropfkörpers bei Abwasser mit relativ geringem BSB oder als Feinbehandlungsschritt nach einem Belebtschlammverfahren oder einem hochbelasteten Tropfkörper. Die Verwendung von Tropfkörpern in der Nahrungsmittelproduktion geht aufgrund des relativ großen Flächenbedarfs und möglicher Verfahrensprobleme durch Verstopfungen zurück.

#### Beispielanlagen

Wird in den Branchen Fisch, Molkereiprodukte, Getränke und pflanzliche Öle und Fette eingesetzt. Hochlasttropfkörper werden in einigen Molkereien im Vereinigten Königreich benutzt.

### **4.5.3.1.6 Biohochreaktoren<sup>24</sup> (T15)**

#### Beschreibung

Prozessabwässer aus der Nahrungsmittelproduktion sind oft so stark organisch belastet, dass die herkömmliche aerobe Behandlung nicht ausreicht. Es ist also eine Behandlung erforderlich, um den BSB vor der Weiterbehandlung, z. B. in einer kommunalen Kläranlage, auf ein akzeptables Maß zu senken. Biohochreaktoren oder VorbehandlungsfILTER sind eigens konzipierte Tropfkörper (siehe Abschnitt 4.5.3.1.5), die mit hohen organischen Belastungen arbeiten und den BSB stark reduzieren können.

Für diese Technik werden oberirdische Tanks eingesetzt, die Kunststofffüllkörper mit großer Oberfläche enthalten. Ein mikrobieller Film haftet den Füllkörpern an und baut das organische Material ab. Das Abwasser wird oft nochmals über den Biohochreaktor geführt, um eine weitergehende Behandlung zu erzielen. Das Abwasser aus diesen Einheiten wird dann einem herkömmlichen biologischen Verfahren zugeführt.

#### Erreichbare Umweltvorteile

Weniger BSB/CSB, geringere Phosphor- und Stickstoffkonzentration.

#### Medienübergreifende Auswirkungen

Potenzielle Geruchsbelästigung, Lärmemissionen und hohe Überschuss-Schlammproduktion.

#### Betriebsdaten

Kunststoffmedien, wie sie in Biotürmen verwendet werden, haben ein Oberflächen-Volumen-Verhältnis von 100 – 240 m<sup>2</sup>/m<sup>3</sup>. Für Raumbelastungen von 0,5 kg BSB<sub>5</sub>/m<sup>3</sup>/Tag werden Abbauraten von mehr als 90 % gemeldet; bei Raumbelastungen von 2,5 kg BSB<sub>5</sub>/m<sup>3</sup>/Tag können bis zu 60 % abgebaut werden. Es kann zu Verstopfungen und instabilen Schlammverhältnissen kommen. Durch das Einblasen von Luft in den Bioturm kann Lärm entstehen.

#### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion, deren Abwasser einen hohen organischen Gehalt aufweist.

#### Anlass für die Umsetzung

Biohochreaktoren sind ein effektives Mittel zur Reduzierung des BSB auf Werte, die Haushaltsabwasserniveau entsprechen.

#### Referenzliteratur

[1, CIAA, 2002, 13, Environment Agency of England and Wales, 2000, 145, Metcalf & Eddy, 1991]

### **4.5.3.1.7 Rotationstauchkörper (T16)**

#### Beschreibung

Ein Rotationstauchkörper besteht aus einer Reihe dicht beieinander angeordneter runder Scheiben aus Polystyrol oder Polyvinylchlorid. Die Scheiben tauchen in das Abwasser ein und rotieren langsam darin.

<sup>24</sup> Anm. d. UBA-Bearb.: Diesen Begriff gibt es so nicht in D.

Während des Betriebs setzt sich ein biologischer Rasen an der Oberfläche der Scheiben fest und überzieht schließlich die gesamte benetzte Oberfläche. Durch die Rotation der Scheiben kommt diese Biomasse abwechselnd mit den organischen Stoffen im Abwasser und mit der Atmosphäre, aus der sie Sauerstoff aufnimmt, in Kontakt. Durch die Rotation wird außerdem überschüssige Biomasse von den Scheiben entfernt, sodass sie aus dem Tropfkörper in Absetzbecken transportiert werden kann.

### Erreichbare Umweltvorteile

Weniger BSB, geringere Phosphor- und Stickstoffkonzentration, weniger suspendierte Feststoffe.

### Medienübergreifende Auswirkungen

Potenzielle Geruchsbelästigung.

### Betriebsdaten

Sachgerecht geplante Rotationstauchkörper sind recht zuverlässig, da eine große Menge Biomasse vorhanden ist (geringe spezifische Schlammbelastung). Die große Biomasse macht es auch möglich, dass hydraulische und organische Spitzenwerte effektiver behandelt werden. Wenn dieses System mit Propfenströmung in hintereinander geschalteten Stufen durchgeführt wird, lassen sich Kurzschlüsse vermeiden und Frachtspitzen abfangen. Angaben zufolge kann es zum Blockieren der Scheiben kommen.

Für Rotationstauchkörper wird die Phosphoreliminierungseffizienz mit 8 – 12 % angegeben.

### Anwendbarkeit

In weiten Bereichen der Nahrungsmittelproduktion einsetzbar, z. B. zur Senkung des BSB und des Gehalts an Phosphor, Stickstoff und suspendierten Feststoffen.

### Beispielanlagen

Wird in der Fischverarbeitung und bei der Gewinnung pflanzlicher Öle und Fette eingesetzt.

### Referenzliteratur

[145, Metcalf & Eddy, 1991]

#### **4.5.3.1.8 Belüftete und geflutete Biofilter (BAFF) – Getauchte und belüftete Biofilter (SBAF) (T17)**

### Beschreibung

Belüftete und geflutete Biofilter (BAFF) sowie getauchte und belüftete Biofilter (SBAF) sind Zweifach-Systeme (biologische Reduktion und Filtration) mit suspendierter/anhaftender Biomasse, die sich am besten als biologisch aktive Anlagen beschreiben lassen. Die porösen Füllkörper haben große innere Oberflächen, um das bakterielle Wachstum zu fördern.

### Erreichbare Umweltvorteile

Geringerer BSB/CSB.

### Betriebsdaten

Etwa alle 24 Stunden findet eine Spülung statt, mit der überschüssige Biomasse entfernt wird. Daher ist eine Nachklärung nicht erforderlich. Für die Behandlung des Spülwassers wird eine Sedimentations- oder Flotations-einheit benötigt.

### Anwendbarkeit

Primär zur weiteren Aufbereitung von häuslichem Abwasser genutzt; allerdings finden SBAF zunehmend Anwendung in der Nahrungsmittelproduktion.

### Wirtschaftliche Aspekte

Es wird berichtet, dass BAFF-Reaktoren eine kosteneffektive Behandlung von Abwässern mit löslichen organischen Stoffen erlauben.

### Beispielanlagen

Wird in den Branchen Fleisch, Obst und Gemüse, Molkereiprodukte und Getränke angewendet.

### Referenzliteratur

[13, Environment Agency of England and Wales, 2000]

#### 4.5.3.1.9 Aerobe Schnell- und Ultraschnellfilter (T18)

##### Beschreibung

Hoch und ultrahoch belastete aerobe Filter erlauben höhere Befruchtungsraten als gewöhnliche aerobe Systeme. Im Verfahren wird das Abwasser mit einer hohen Umwälzrate durch eine integrierte Anordnung von Düsen geführt. Durch die Düsen wird Luft eingebracht, was zu starken Scherkräften auf die Bakterien und einem erheblichen Grad an Turbulenz/Oxygenierung führt. Es sind diese auf die Bakterien wirkenden starken Scherkräfte, die dieses Verfahren von anderen aeroben Techniken unterscheiden, d. h. die Mikroorganismen passieren die Düse, sodass nur sehr kleine Bakterien im System auftreten, wogegen in anderen Systemen diese Scherkräfte fehlen und höhere Lebensformen ebenfalls vorhanden sind.

##### Erreichbare Umweltvorteile

Geringerer BSB/CSB.

##### Medienübergreifende Auswirkungen

Die mit diesen Filtern erzeugte Abwasserqualität ist für eine Abwassereinleitung in Gewässer nicht ausreichend.

##### Betriebsdaten

Ultrahoch belastete aerobe Systeme erlauben eine potenzielle Schlammbelastung, die die herkömmlicher aerober Behandlungen um das 50- bis 100-fache übersteigt. Trotzdem ist eine zweite aerobe Stufe mit geringerer Befruchtung nötig, da keine für die Einleitung in Gewässer geeignete Abwasserqualität erzielt wird.

##### Anwendbarkeit

Breiter Anwendungsbereich der Nahrungsmittelproduktion.

##### Wirtschaftliche Aspekte

Geringere Investitionskosten.

##### Anlass für die Umsetzung

Geringere Anlagengröße und Investitionskosten.

##### Beispielanlagen

Wird im Fischsektor angewendet.

#### 4.5.3.2 Anaerobe Verfahren

In Abwesenheit von Sauerstoff wird organisches Material abgebaut, wobei Methan ( $\text{CH}_4$ ) als Nebenprodukt entsteht und zum Heizen der Reaktoren verwendet wird. In herkömmlichen anaeroben Verfahren sind die Reaktoren normalerweise nicht beheizt, aber bei anaeroben Hochleistungsverfahren werden die Reaktoren in der Regel beheizt. In beiden Fällen muss eine Reaktortemperatur von etwa 30 – 35 °C (mesophil) oder 45 – 50 °C (thermophil) eingehalten werden. Ob Wärme für das Verfahren benötigt wird, ist in erster Linie von der Temperatur des Zuflusses abhängig [145, Metcalf & Eddy, 1991, 200, CIAA, 2003].

Obwohl das Wachstum der Mikroorganismen unter anaeroben Bedingungen langsamer abläuft als in aerobem Milieu, erreicht man mit anaeroben Verfahren bei hochbelastetem Abwasser eine höhere BSB-Raumbelastung (in Bezug auf kg BSB/m<sup>3</sup> Reaktorvolumen). Anaerobe Verfahren werden in Branchen eingesetzt, in denen ein hoher Gehalt an löslichem und schnell biologisch abbaubarem organischem Material anfällt, und wo die Belastung des Abwassers im Allgemeinen über einem CSB-Wert von 1.500 – 2.000 mg/l liegt. Für die Nahrungsmittelproduktion beschränkt sich die anaerobe Behandlung des Abwassers größtenteils auf stark verunreinigtes Abwasser mit einem CSB-Wert zwischen 3.000 und 40.000 mg/l, z. B. in den Branchen Zucker, Stärke, Obst und Gemüse, alkoholische Getränke. Auch bei weniger verunreinigtem Wasser mit einem CSB-Wert zwischen 1.500 und 3.000 mg/l, z. B. aus Brauereien, Molkereien, dem Fruchtsaft- und dem Mineralwassersektor und dem Sektor der alkoholfreien Erfrischungsgetränke, gab es kürzlich Erfolge mit der Anwendung bestimmter anaerober Systeme [65, Germany, 2002]. Weniger wirkungsvoll ist die Behandlung jedoch dort, wo Volumen und Belastung stark schwanken, z. B. bei Abwasser aus der Obst- und Gemüseverarbeitung.

Einer der grundlegenden Aspekte der anaeroben Behandlung von Abwasser ist die Umwandlung des weitaus größten Teils des organischen Kohlenstoffs in Methan. Damit wird erreicht, dass der Kohlenstoff nicht für weiteres Zellwachstum zur Verfügung steht. Bei aeroben Verfahren ist das Gegenteil der Fall: dort wird die überwiegende Menge des organischen Kohlenstoffs in neue Zellen umgewandelt, was zur Bildung von Überschuss-Schlamm führt, der entweder anderweitig behandelt oder außerhalb der Anlage entsorgt werden muss. Bei anaeroben Verfahren fällt sehr viel weniger Überschuss-Schlamm an. Außerdem hat das entstandene Methan einen hohen Brennwert und kann als Brennstoff, z. B. an anderer Stelle in der Anlage, wiederverwendet werden.

Ein anaerobes System alleine würde jedoch nicht zu der Wasserqualität führen, die eine Einleitung in Gewässer erlauben würde. Daher folgt auf eine anaerobe Behandlung in der Regel ein aerobes Verfahren (siehe Abschnitt 4.5.3.1), da letzteres zu niedrigeren absoluten Endwerten führt. Außerdem wird Schwefelwasserstoff entfernt und damit sichergestellt, dass das Abwasser gut belüftet ist, was die Reduzierung des verbliebenen BSB unterstützt. Die aus einer anaeroben Anlage gewonnene Energie kann äquivalent sein zu der Energie, die in einer aeroben Anlage verbraucht wird. Unter bestimmten Umständen kann die aerobe Behandlung auch erst in der nachfolgenden kommunalen Kläranlage stattfinden. Das hängt von der Kläranlage ab, die das Abwasser aufnimmt, und von dem Saldo zwischen den Kosten für die Abwasserbehandlung und einer betriebseigenen aeroben Behandlungsstufe. Vor der Ableitung in eine kommunale Kläranlage kann das anaerob behandelte Abwasser noch im Betrieb einer Oberflächenbelüftung unterzogen werden. Dies geschieht normalerweise, bevor das Abwasser in eine Kläranlage abgegeben wird, in einem Nachbehandlungsbecken, in dem gelöster Sauerstoff zur Verfügung steht.

Die methanogenen Bakterien, die in der letzten Stufe des anaeroben Verfahrens aktiv sind und das Methan produzieren, müssen vor einer zu großen Menge an Chlor- und Schwefelverbindungen, zu hohem pH-Wert und Temperaturschwankungen geschützt werden. In der Versäuerungsstufe des Verfahrens überwiegen andere Bakterien, die viele dieser problematischen Verbindungen abbauen. Aufgrund des langsamen Wachstums der Mikroorganismen wird Phosphor nicht entfernt. Es findet auch keine Nitrifikation und Denitrifikation statt, sodass auch Stickstoff nicht durch eine anaerobe Behandlung entfernt werden kann.

Moderne Reaktorbauweisen erlauben höhere Belastungsraten, erhöhen die Produktion von Biogas oder bieten eine bessere Stabilität. Sobald sich die Bakterienpopulation in einem solchen System an das Abwasser angepasst hat, verbessert sich die Stabilität.

Die technischen Einrichtungen zur anaeroben Abwasserbehandlung sind unabhängig vom Standort immer ähnlich gestaltet. Es gibt ein Abwassersammelbecken oder einen Misch- und Ausgleichstank, aus dem das Abwasser in einen Vorbehandlungsanlage fließt oder gepumpt wird. Die Vorbehandlungsverfahren sind die gleichen wie die für aerobe Systeme beschrieben.

Nach der Vorbehandlung gelangt das Abwasser in einen Konditionierungs- oder Puffertank, in dem es „konditioniert“ wird. Dort wird beispielsweise der pH-Wert korrigiert oder es werden Nährstoffe zugegeben, bevor das Abwasser über ein Verteilungssystem dem Bioreaktor zugeführt wird. In älteren anaeroben Reaktoren konnten die ersten Stufen der anaeroben Verstoffwechslung bereits im Konditionierungstank ausgelöst werden (deshalb häufig auch als Vorversäuerungstank bezeichnet). Bei modernen Reaktoren finden die gesamten Stoffwechselprozesse innerhalb des Reaktors statt. Der Konditionierungstank wird daher im Allgemeinen nur für die Einstellung des pH-Werts und für die Zugabe der Nährstoffe benötigt.

Die Behandlung findet im Reaktor statt und das entstehende Biogas muss aufgefangen werden. Weitere Komponenten sind häufig ein Tank für die Lagerung des Schlammes, die Behandlung des Entlüftungsgases aus dem Schlammstank sowie Einrichtungen zur Abwasservorbehandlung.

Übliche Leistungsparameter anaerober Verfahren sind in Tabelle 4.58 aufgeführt.

| Verfahren                        | CSB des Zulaufs<br>(mg/l) | Hydraulische Verweilzeit<br>(h) | Organische Raumbelastung<br>(kg CSB/m <sup>3</sup> pro Tag) | Verringerung des CSB<br>(%) |
|----------------------------------|---------------------------|---------------------------------|---|-----------------------------|
| Anaerobe Abwasserteiche          |                           |                                 | 0,6 – 1   |                             |
| Anaerobes Kontaktverfahren       | 1.500 – 5.000             | 2 – 14                          | 0,5 – 5,3   | 75 – 90                     |
| Festbettverfahren                | 10.000 – 70.000           | 24 – 48                         | 1 – 15  | 75 – 85                     |
| UASB                             | 5.000 – 15.000            | 4 – 12                          | 2 – 12<br>(- 60)  | 75 – 85                     |
| Expanded-Bed-Reaktor             | 5.000 – 10.000            | 5 – 10                          | 5 – 30  | 80 – 85                     |
| Fließbettverfahren               |                           |                                 | 40 – 60   |                             |
| Reaktor mit interner Zirkulation |                           |                                 | 31  |                             |

**Tabelle 4.58: Übliche Verfahrens- und Leistungswerte anaerober Abwasserbehandlungsverfahren] [145, Metcalf & Eddy, 1991, 159, CIAA-CEFS, 2003]**

In Tabelle 4.59 sind Beispiele für Betriebsprobleme aufgeführt, die bei anaeroben Verfahren auftreten können.

| Problem  | Lösungsmöglichkeit  |
|--|---|
| Mangel an Makronährstoffen                         | Normalerweise wird das Verhältnis BSB <sub>5</sub> :N:P bei 500:5:1 gehalten  |
| pH-Wert  | Der pH-Wert wird zwischen 6,8 und 7,5 gehalten  |
| Temperatur   | Die optimale Temperatur für mesophile Bakterien liegt bei 35 – 37 °C  |
| Mangel an Mikronährstoffen                         | Minimalmengen für Mikronährstoffe, insbesondere für Fe, Ca, Mg und Zn, je nach eingesetztem spezifischen Verfahren, werden aufrechterhalten   |
| Verstopfung der in den Reaktor führenden Leitungen | Wirksames Rechen/Sieben und weitere Vorbehandlung sind notwendig  |
| Überlastung  | Es muss sichergestellt werden, dass die ursprüngliche hydraulische Last und die Belastung mit Feststoffen und organischem Material nicht die Empfehlungen des Herstellers übersteigen |

**Tabelle 4.59: Übliche Probleme, die bei biologischen Behandlungsverfahren auftreten können [13, Environment Agency of England and Wales, 2000]**

#### 4.5.3.2.1 Anaerobe Abwasserteiche (T19)

Anaerobe Abwasserteiche ähneln aeroben Abwasserteichen (siehe Abschnitt 4.5.3.1.4) mit dem Unterschied, dass die anaeroben Teiche nicht durchmischt werden [145, Metcalf & Eddy, 1991]. Durch die Freisetzung von Schwefelwasserstoff können Geruchsprobleme auftreten [208, CIAA-AAC-UFE, 2003]<sup>25</sup>.

Die Tiefe der anaeroben Abwasserteiche in der Getränkeindustrie wird mit über 2 m angegeben.

#### 4.5.3.2.2 Anaerobe Kontaktverfahren T(20)

##### Beschreibung

Das anaerobe Kontaktverfahren ist dem aeroben Belebtschlammverfahren vergleichbar, da Trennung und Rezirkulation der Biomasse vorgesehen sind. Unbehandeltes Abwasser wird mit dem Rücklaufschlamm vermischt und dann in einem Reaktor unter Luftabschluss fermentiert.

<sup>25</sup> Anm. d. UBA-Bearb.: In Deutschland gibt es solche Teiche nur mit einer Abdeckung, z. B. in Form einer Membranhülle zum Auffangen von H<sub>2</sub>S.

### Erreichbare Umweltvorteile

Geringere BSB-/CSB-Werte.

### Betriebsdaten

Im Vergleich zu den Hochleistungsverfahren mit UASB-Reaktoren (siehe Abschnitt 4.5.3.2.4) und Hochleistungsschlammbett- (EGSB) und Wirbelschichtreaktoren (siehe Abschnitt 4.5.3.2.7) entstehen bei den Kontaktstabilisierungsverfahren geringere Mengen an Biomasse im Reaktor, die daher mit vergleichsweise geringerer Raumbelastung (in der Regel bis zu 5 kg CSB/m<sup>3</sup> pro Tag) arbeiten. Ihr Hauptvorteil liegt jedoch in ihrem relativ störungsfreien Betrieb und insbesondere darin, dass es keine Probleme mit Verstopfungen gibt.

Da der anaerobe Schlamm das Gas außerhalb des Reaktors produziert und das Gasvolumen ständig zunimmt, muss häufig eine Entgasungseinheit zwischen Methanreaktor und Schlammseparatoreinheit eingesetzt werden. Das Entgasen kann mittels Vakuumentgasung, Strippung, Kühlung oder mit langsamen Rührwerken erfolgen. Mit einer solchen Maßnahme kann das Verfahren mit Verweilzeiten von 6 – 14 Stunden betrieben werden.

### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion, in denen Abwasser mit einer hohen Menge an gelösten Feststoffen anfällt.

### Anlass für die Umsetzung

Dieses Verfahren bietet einen relativ störungsfreien Betrieb ohne Verstopfungsprobleme.

### Beispielanlagen

Wird im Fleischsektor und im Zuckersektor angewendet.

### Referenzliteratur

[13, Environment Agency of England and Wales, 2000, 145, Metcalf & Eddy, 1991]

#### **4.5.3.2.3 Anaerobfilter (T21)**

### Beschreibung

In Anaerobfiltern wachsen die anaeroben Bakterien auf einem Pack- oder Füllmaterial. Das Bewuchsmaterial hält die Biomasse innerhalb des Reaktors; außerdem unterstützt es die Trennung des Gases von der flüssigen Phase. Die Strömung in diesem System kann aufwärts oder abwärts gerichtet sein.

### Erreichbare Umweltvorteile

Verringerung des BSB/CSB-Gehalts und Stabilisierung des Überschuss-Schlammes.

### Betriebsdaten

Da die Bakterien auf dem Medium zurückgehalten und nicht in das Abwasser ausgewaschen werden, können Verweilzeiten im Bereich von 100 Tagen erreicht werden.

### Anwendbarkeit

Geeignet zur Behandlung stark verunreinigter Abwässer mit einem CSB-Wert zwischen 10.000 und 70.000 mg/l.

### Referenzliteratur

[1, CIAA, 2002, 13, Environment Agency of England and Wales, 2000, 65, Germany, 2002, 145, Metcalf & Eddy, 1991]

#### **4.5.3.2.4 UASB-Reaktoren (Upflow anaerobic sludge blanket) (T22)**

### Beschreibung

In einem UASB-System wird das Abwasser am Boden des Reaktors zugeführt, um eine gleichmäßige Verteilung zu erreichen. Das Abwasser strömt durch eine Schicht aus Bakterien, die sich zu kugelförmigen Teilchen (Pellets) zusammengeballt haben. Dank der guten Absetzeigenschaften werden sie nicht so leicht aus dem System ausgeschwemmt. Die Bakterien reagieren mit dem Abwasser. Durch die natürliche Konvektion steigt im Reaktor eine Mischung aus Gas, behandeltem Abwasser und Schlammpellets nach oben. Mit patentierten Drei-Phasen-Separatoren wird das behandelte Abwasser von den Feststoffen (Biomasse) und dem Biogas getrennt.

Erreichbare Umweltvorteile

Geringere BSB-/CSB-Werte.

Betriebsdaten

Es werden Raumbelastungen von bis zu 60 kg CSB/m<sup>3</sup> pro Tag gemeldet, aber 10 kg CSB/m<sup>3</sup> pro Tag mit einer hydraulischen Verweilzeit von 4 Stunden ist eher üblich.

In Tabelle 4.60 ist die gemeldete Leistungsfähigkeit eines UASB-Reaktors in einer Brauerei angegeben.

|  |             |
|--|-------------|
| <b>Raumbelastung<br/>(kg CSB/m<sup>3</sup> und Tag)<br/>[oder: kg CSB/m<sup>3</sup>*d]</b>     | 5 – 10      |
| <b>CSB des behandelten<br/>Abwassers<br/>(mg/ml)</b>   | 500 – 1.000 |
| <b>Menge des erzeugten<br/>Schlamm pro kg<br/>entfernter CSB-Fracht<br/>(kg Feststoffe/kg)</b> | 0,04 – 0,08 |
| Für die Einleitung in Gewässer ist eine weitere<br>Behandlung notwendig                        |             |

**Tabelle 4.60: Angegebene Leistungsfähigkeit eines UASB-Reaktors in einer Brauerei**

Ein Nachteil von UASB-Reaktoren ist die Empfindlichkeit des Verfahrens gegenüber lipophilen Stoffen. Der Fettgehalt im Abwasser muss unter 50 mg/l liegen, sonst wird das Verfahren beeinträchtigt. Ein besonderer Vorteil des Verfahrens ist andererseits die Bildung von Pellets. Diese erlauben nicht nur eine schnelle Reaktivierung nach monatelanger Betriebsunterbrechung, sondern auch den Verkauf überschüssiger Schlamm-pellets, z. B. zur Animpfung neuer Systeme.

Anwendbarkeit

Dieses Verfahren ist insbesondere geeignet für Abwasser mit einem niedrigen Feststoffgehalt und relativ geringem CSB (< 2.000 mg/l). Außerdem wird es eingesetzt, wenn nur eine kleine Fläche (oder nur wenig Platz vorhanden ist) zur Verfügung steht. Von den anaeroben Systemen sind Schlamm-bettreaktoren derzeit die in der Nahrungsmittelproduktion am weitesten verbreiteten Reaktoren.

Beispielanlagen

Werden in den Branchen Fleisch, Obst und Gemüse, Brauwirtschaft, Stärke und Zucker eingesetzt.

Referenzliteratur

[13, Environment Agency of England and Wales, 2000, 136, CBMC - The Brewers of Europe, 2002, 208, CIAA-AAC-UFE, 2003]

**4.5.3.2.5 Reaktoren mit interner Zirkulation (T23)**Beschreibung

Reaktoren mit interner Zirkulation stellen eine spezielle Konfiguration des UASB-Verfahrens (siehe Abschnitt 4.5.3.2.4) dar. Dabei werden zwei UASB-Reaktoren übereinander angeordnet, von denen der eine hoch und der andere niedrig belastet ist. Das sich in der ersten Stufe ansammelnde Biogas steigt nach oben und bewirkt eine interne Zirkulation von Abwasser und Schlamm; daher der Name dieses Verfahrens.

Erreichbare Umweltvorteile

Geringere BSB-/CSB-Werte.

Betriebsdaten

Einer der wichtigsten Vorteile des Reaktors mit interner Zirkulation liegt darin, dass er unabhängig von Schwankungen der zugeführten Ströme und Belastungen in gewissem Maße einer Selbstregulierung unterliegt. Mit zunehmender Belastung steigt die Menge des erzeugten Methans, das wiederum die Zirkulation erhöht und dadurch das zulaufende Abwasser verdünnt. Übliche Raumbelastungen für diesen Prozess liegen im Bereich von 15 – 35 kg CSB/m<sup>3</sup> pro Tag.

### Anwendbarkeit

Breiter Anwendungsbereich der Nahrungsmittelproduktion.

### Referenzliteratur

[13, Environment Agency of England and Wales, 2000]

#### 4.5.3.2.6 Hybrid-UASB-Reaktoren (T24)

##### Beschreibung

Der Hybridprozess ist eine Variante des konventionellen UASB-Verfahrens (siehe Abschnitt 4.5.3.2.4). Dazu gehört eine mit einem Medium bepackte Zone oberhalb der offenen Hauptzone. Dort können die nicht zusammengeballten Bakterien gesammelt und zurückgehalten werden, die in einem konventionellen UASB-Reaktor verlorengehen würden. Die untere Schlammzone arbeitet auf die gleiche Weise wie in einem herkömmlichen UASB-Reaktor. In ihr findet der größte Teil des biologischen Abbaus des organischen Materials statt. Die in der Packzone vorhandenen Mikroorganismen und Medien bewirken in gewissem Umfang eine Feinfiltration, dienen als Reserve für biologische Feststoffe und verhindern ein Auswaschen der Biomasse aus dem Reaktor.

##### Erreichbare Umweltvorteile

Geringere BSB-/CSB-Werte.

##### Betriebsdaten

Anaerobe Hybridreaktoren sind schnelle Systeme mit Raumbelastungen von normalerweise 10 bis 25 kg CSB/m<sup>3</sup> pro Tag.

### Anwendbarkeit

Breiter Anwendungsbereich in der Nahrungsmittelproduktion.

### Referenzliteratur

[13, Environment Agency of England and Wales, 2000]

#### 4.5.3.2.7 Wirbelbett- und Wirbelschicht-Reaktoren (T25)

##### Beschreibung

Diese Reaktoren sind den Anaerobfiltern ähnlich (siehe Abschnitt 4.5.3.2.3). Wenn Trägermaterial und Biomasse vollständig miteinander vermischt sind, handelt es sich um eine „**Wirbelschicht**“. Wenn beides nur teilweise vermischt ist, spricht man von „**Wirbelbett**“.

##### Erreichbare Umweltvorteile

Verringerung des BSB/CSB-Gehalts und Stabilisierung des Überschuss-Schlammes.

##### Betriebsdaten

Um hohe Raumbelastungen im Bereich von 15 – 35 kg CSB/m<sup>3</sup> und Tag zu erreichen, ist es absolut notwendig, den Methanreaktor mit einem möglichst konstanten Volumenstrom von ausreichend vorversäuertem, feststoff-freiem Abwasser zu versorgen. Aus diesem Grund werden die industriellen Systeme als zweistufige Systeme gebaut, d. h. sie haben eine getrennte Vorversäuerungsstufe.

Im **Wirbelschicht**-Reaktor ist das Trägermaterial ständig in Bewegung, wobei sich die Schicht um 50 % oder mehr ausdehnt. Das Trägermaterial (gewöhnlich Sand, aber manchmal auch Bimsstein oder Kunststoffpellets) wird durch die hohe Rezirkulationsgeschwindigkeit in Suspension gehalten. Die Rezirkulation muss zwar ausreichen, um das Trägermaterial in Suspension zu halten, darf aber nicht zu stark sein, weil sich ansonsten die Biomasse vom Trägermaterial ablösen kann.

In einem **Wirbelbett**-Reaktor gibt es noch Stützmaterial, das häufig nichts anderes ist als Sand oder synthetisches Kunststoffmaterial. Oft werden leichte Materialien verwendet, damit eine schwächere Aufwärtsströmung zur Verwirbelung der Schicht ausreicht. Die Partikelgröße liegt normalerweise im Bereich von 0,3 bis 1,0 mm.

### Anwendbarkeit

Anwendbar in Anlagen der Nahrungsmittelproduktion mit gering verschmutztem Abwasser mit einem durchschnittlichen CSB zwischen 1.500 und 3.600 mg/l.

Beispielanlagen

Wird bei der Zuckerherstellung eingesetzt.

Referenzliteratur

[13, Environment Agency of England and Wales, 2000, 65, Germany, 2002]

#### 4.5.3.2.8 EGSB-Reaktoren (Expanded granular sludge bed reactors) / Hochleistungsreaktoren (T26)

Beschreibung

EGSB-Reaktoren arbeiten mit dem gleichen granulat-ähnlichen Pellet-Schlamm wie UASB-Reaktoren (siehe Abschnitt 4.5.3.2.4), allerdings arbeiten EGSB-Reaktoren mit einer höheren Schicht dieses Schlammes und schneller steigendem Wasser. Der Reaktor, in dem behandeltes Wasser zur Rezirkulation verwendet wird, ist mit einem Drei-Phasen-Separator (Feststoff, Flüssigkeit, Gas) ausgestattet<sup>26</sup>.

Erreichbare Umweltvorteile

Geringere BSB-/CSB-Werte und niedrigerer Stickstoffgehalt. Geringerer Bedarf an elektrischer Energie, da das entstandene Methan in der KWK-Anlage verbrannt und somit Strom erzeugt werden kann (z. B. in einer Melassedestillerie).

Betriebsdaten

Es werden Raumbelastungen von 30 kg CSB/m<sup>3</sup> \* Tag gemeldet. Das Wasser strömt in der Regel mit 3 m/h nach oben, im Vergleich zu 1 m/h in einem UASB-Reaktor. Bei EGSB-Reaktoren dauert die Phase der Inbetriebnahme/Akklimatisation nicht lange.

Tabelle 4.61 zeigt die gemeldete Leistungsfähigkeit eines EGSB-Reaktors in einer Brauerei.

|  |             |
|--|-------------|
| <b>Raumbelastung<br/>(kg CSB/m<sup>3</sup> * Tag)</b>  | 15 – 25     |
| <b>CSB des behandelten Abwassers<br/>(mg/ml)</b>   | 500 – 1.000 |
| <b>Menge des erzeugten Schlammes<br/>pro kg entfernter CSB-Fracht<br/>(kg Feststoffe/kg)</b> | 0,04 – 0,08 |
| Für die Einleitung ins Gewässer ist eine weitere Behandlung notwendig                        |             |

**Tabelle 4.61: Angegebene Leistungsfähigkeit eines EGSB-Reaktors in einer Brauerei**

In einer Beispiel-Melassedestillerie werden in einem EGSB-Reaktor das Brüdenkondensat aus der Kondensationseinheit und das Lutterwasser aus der Destillation/Rektifikation behandelt. Der Reaktor verringert den CSB und die Stickstoffbelastung in der nachgeschalteten Belebtschlammanlage. Das entstandene Methan wird in einer KWK-Anlage verbrannt, um Strom und Wärme zu erzeugen. Der hohe Wirkungsgrad des Reaktors führt dazu, dass nur geringe Mengen an Überschuss-Schlamm produziert werden. In dieser Beispielanlage wird er in einem Dekanter konzentriert und für landwirtschaftliche Zwecke eingesetzt oder in einer kommunalen Kläranlage entsorgt.

Anwendbarkeit

Breiter Anwendungsbereich in der Nahrungsmittelproduktion.

Anlass für die Umsetzung

Verringerung der Kosten für die Abwasserbehandlung und zuverlässige Einhaltung der Einleitgrenzwerte.

Beispielanlagen

Wird in den Branchen Zucker, Getränke und Brauwirtschaft eingesetzt.

Referenzliteratur

[65, Germany, 2002, 136, CBMC - The Brewers of Europe, 2002]

<sup>26</sup> Anm. d. UBA-Bearb.: Die Rezirkulation kann sowohl extern als auch intern erfolgen (IC-Reaktor-internal circulation).

### 4.5.3.3 Kombinierte aerobe und anaerobe Verfahren

#### 4.5.3.3.1 Membranbioreaktoren (MBR) (T27)

##### Beschreibung

Ein MBR ist eine Variante mit herkömmlichem Belebtschlamm, bei der sich mehrere Membranmodule oder Kartuschen innerhalb des Reaktorbeckens befinden. Nach der biologischen Behandlung wird die Schlamm-Wassermischung unter statischem Druck in die Membraneinheit gepumpt, in der Feststoffe und Flüssigkeit aufgetrennt werden. Das saubere Abwasser wird abgeleitet und der konzentrierte Schlamm in den Bioreaktor zurückgeführt. Der Membranbioreaktor kann entweder unter **aeroben oder anaeroben** Bedingungen gefahren werden und vergrößert dadurch die Anzahl geeigneter Chemikalien, die z. B. zur Reinigung der in der biologischen Behandlungsstufe befindlichen Membranen genutzt werden.

##### Erreichbare Umweltvorteile

Geringere BSB-/CSB-Werte.

##### Medienübergreifende Auswirkungen

Höherer Energieverbrauch als bei konventionellen Belebtschlammverfahren. Außerdem wird durch Ablagerungen auf den Membranen (Fouling) zusätzliches Abwasser produziert<sup>27</sup>.

##### Betriebsdaten

Ein MBR kann mit einer großen Bandbreite an Schlammbelastung betrieben werden. Ein höherer Reinigungsgrad kann auf verschiedene Arten erzielt werden, z. B. kann durch Erhöhung des statischen Drucks die Menge des gelösten Sauerstoffs angehoben werden, was den Stoffübergang unterstützt. Außerdem kann man zwecks Optimierung des Verfahrens Sauerstoff statt Luft einsetzen oder ein mehrstufiges System betreiben. Bei fett- und ölhaltigen Abwässern kann die Konzentration auf unter 15 mg/l gesenkt werden.

Ein MBR bietet eine hochwirksame Abtrennung der Biomasse und ermöglicht eine Biomassenkonzentration innerhalb des Bioreaktors, die bis zum 10-fachen der normalerweise in einem konventionellen System erreichbaren Konzentration beträgt. Wenn ein Membranbioreaktor eingesetzt wird, ist keine Nachklärung erforderlich. Es kann eine sehr große Bandbreite der Konzentration im belebten Schlamm (MLSS) erreicht werden, d. h. 12.000 – 17.000 mg/l. Abbildung 4.39 zeigt ein vereinfachtes Prozessdiagramm eines Membranbioreaktors.

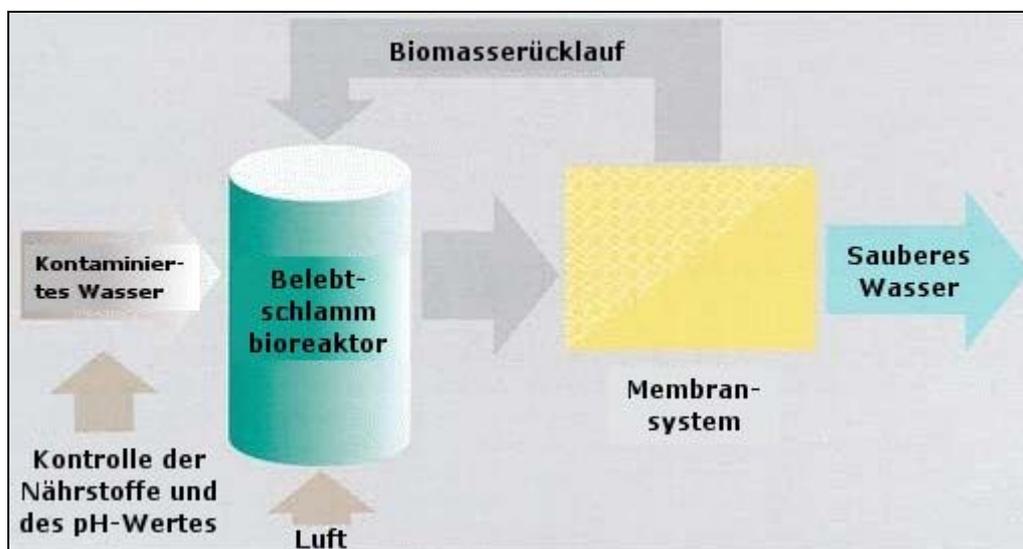


Abbildung 4.39: Vereinfachtes Prozessflussbilddiagramm eines Membranbioreaktors. [155, UBC Civil Engineering, 2003]

Der Energieverbrauch für das Pumpen kann erheblich höher sein als bei herkömmlicher Belebtschlammbehandlung, kann aber minimiert werden, wenn das Abwasser im freien Gefälle zuläuft. Eine Beispielmolkerei in Irland behandelt 9.000 m<sup>3</sup> Abwasser pro Tag, die unter Erfüllung hoher Einleitungsstandards in ein Ober-

<sup>27</sup> Anm. d. UBA-Bearb.: Reinigung und Rückspülung der Membranen.

flächengewässer eingeleitet werden. Durch den Abwasserzulauf im freien Gefälle wird das Verfahren weniger energieaufwendig.

Ein großes Problem kann das Fouling der Membranen darstellen. Um dieses Problem unter Kontrolle zu bekommen, werden Belüftung und Rückspülung eingesetzt, wodurch möglicherweise mehr Abwasser entsteht. Entspannungsfotation (siehe Abschnitt 4.5.2.6) wird eingesetzt, um die Membranoberflächen zu spülen und zu reinigen und biologische Ablagerungen zu verhindern.

#### Anwendbarkeit

Membranbioreaktoren können in allen Bereichen der Nahrungsmittelproduktion eingesetzt werden. Diese Technik hat den Vorteil, dass sie nur wenig Platz beansprucht. Das System ist ideal für kleinere Mengen hochbelasteten Abwassers. Es ist besonders dann attraktiv, wenn ein hohes Schlammalter erforderlich ist, um den notwendigen biologischen Abbau der Schadstoffe zu erreichen. Außerdem ist das MBR-Verfahren für die Behandlung von Abwasser, das schwer abbaubare Verbindungen, wie z. B. Phenole, Pestizide, Herbizide und chlorierte Lösungsmittel enthält, geeignet.

#### Wirtschaftliche Aspekte

Hohe Betriebskosten.

#### Beispielanlagen

Wird in den Branchen Fleisch, Obst und Gemüse, Molkereien und Getränke eingesetzt. Angaben zufolge ist der Einsatz im Stärkesektor in der Entwicklung.

#### Referenzliteratur

[13, Environment Agency of England and Wales, 2000, 155, UBC Civil Engineering, 2003, 250, UK TWG, 2004]

### 4.5.3.3.2 Mehrstufige Systeme (T28)

#### Beschreibung

Verschiedene **aerobe** und **anaerobe** Abwasserbehandlungsverfahren können einzeln oder in Kombination eingesetzt werden. Werden sie in einer Kombination hintereinander eingesetzt, spricht man von **mehrstufigen Systemen**. Das Abwasser wird hintereinander in den einzelnen Stufen behandelt, die mit Hilfe von separaten Schlammkreisläufen voneinander getrennt betrieben werden.

#### Erreichbare Umweltvorteile

Verringerung des BSB/CSB-Gehalts und Wiederverwendung des Wassers.

#### Betriebsdaten

Die folgenden Prozesskombinationen werden allgemein für eine aerobe Behandlung eingesetzt:

- Belebtschlamm/Belebtschlamm
- Tropfkörper/Tropfkörper
- Tropfkörper/Belebtschlamm
- Belebtschlamm/Tropfkörper
- Abwasserteiche/Belebtschlamm
- Abwasserteiche/Tropfkörper.

In den Branchen Fleisch, Obst und Gemüse und Getränke kann mit einem zweistufigen biologischen System, bei dem ein aerobes Verfahren dem anaeroben folgt, eine Abwasserqualität erreicht werden, die es erlaubt, das Wasser wiederzuverwenden oder in das Gewässer einzuleiten.

#### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion, in denen hochbelastetes Abwasser anfällt.

#### Beispielanlagen

Wird in den Branchen Fleisch, Obst und Gemüse, Getränke, pflanzliche Öle und Fette und Stärke einsetzbar.

### 4.5.4 Nachsorgende Behandlung des Abwassers

Nach der biologischen Behandlung des Abwassers kann eine weitere Behandlung erforderlich sein, um das Wasser danach als Prozesswasser oder als minderwertiges Waschwasser wiederzuverwenden oder um Einleitungsanforderungen einzuhalten. Der Begriff „Nachsorgende Behandlung des Abwassers“ bezieht sich auf Verfahren, die als „Weitergehende Behandlung“ verstanden werden, wobei Desinfektions- und Sterilisationssysteme mit eingeschlossen sind.

In diesem Dokument ist eine nachsorgende Behandlung des Abwassers eine weitergehende Behandlung des Abwassers, mit der besonders problematische Bestandteile wie Ammoniak, pflanzliche Nährstoffe, gefährliche und prioritär gefährliche Stoffe oder Feststoffreste und organische Verbindungen entfernt werden.

Pflanzliche Nährstoffe wie Stickstoff und Phosphor müssen vor der Einleitung in Oberflächengewässer in empfindlichen Gebieten entfernt werden [209, EC, 1991]. Bei der Auswahl einer richtigen Strategie zur Kontrolle Ablaufwerte der Nährstoffe in das Gewässer ist die Beurteilung folgender Punkte wichtig:

- Eigenschaften des unbehandelten Abwassers
- Art der Kläranlage, die benutzt werden soll
- Umfang der erforderlichen Nährstoffkontrolle
- Notwendigkeit einer saisonalen oder ständigen Entfernung der Nährstoffe.

#### 4.5.4.1 Biologische Nitrifikation/Denitrifikation (T29)

##### Beschreibung

Diese Technik ist eine Variante des Belebtschlammverfahrens. In diesem Abschnitt werden vier unterschiedliche Verfahren beschrieben.

Bei der **vorgeschalteten Denitrifikation**<sup>28</sup> wird der im Abwasser vorhandene Kohlenstoff zur Stickstoffeliminierung besser ausgenutzt. Ammonium durchläuft die vorgeschaltete Denitrifikation unverändert und wird in der Nitrifikationsstufe in Nitrat umgewandelt. Dieses Nitrat wird über die Rezirkulation in die Denitrifikationsstufe zurück gefördert. Hier entsteht in Verbindung mit dem organischen Kohlenstoff  $N_2$ . Vorteil dieser Variante ist der weitgehende Verzicht auf externe Kohlenstoffquellen.

In einem System mit **simultaner Denitrifikation** werden durch Begrenzung des Sauerstoffeintritts in das Becken zielgerichtet aerobe und anoxische Zonen geschaffen. Simultane Denitrifikationssysteme werden hauptsächlich als Umlauf- oder Karussellbecken eingerichtet.

Bei einer **intermittierenden Denitrifikation** werden voll durchmischte Belebtschlammbecken in bestimmten Zeitabständen belüftet. In dem Belebtschlammbecken finden aerobe und anoxische Prozesse nacheinander in demselben Becken statt. Das Ausmaß der Nitrifikation/Denitrifikation kann größtenteils durch Veränderungen der Betriebszeiten den Zulaufbedingungen angepasst werden.

Bei der **Kaskadendenitrifikation** sind verschiedene, aus anoxischen und aeroben Zonen (vorgeschaltete Denitrifikation) bestehende Abteilungen des Beckens ohne Zwischensedimentation mit Pfropfenströmung hintereinander angeordnet. Das unbehandelte Abwasser wird in die erste Kaskade eingeleitet, um eine optimale Ausnutzung des im Abwasser enthaltenen Substrats sicherzustellen. Die Einleitung eines Teilstroms des Rohabwassers in ein nachfolgendes Becken der Kaskade kann die Stickstoffentfernung wesentlich verbessern. Der Rücklaufschlamm wird ins erste Becken geleitet. Es gibt hierbei keine Notwendigkeit einer internen Rezirkulation innerhalb der einzelnen Stufen.

##### Erreichbare Umweltvorteile

Reduzierung der Stickstoffmengen und Energieeinsparung.

##### Betriebsdaten

Diese Technik bietet hohe Reinigungseffizienz, große Prozessstabilität und Zuverlässigkeit, relativ einfache Prozesskontrolle und benötigt nur wenig Raum.

Aus dem Stärkesektor wird berichtet, dass Nitrifikations- und Denitrifikationsreaktionen in einem anoxischen Medium stattfinden, das entweder durch intermittierende Belüftung des Belebtschlammbeckens oder in einer

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<sup>28</sup> Anm. d. UBA-Bearb.: Text entsprechend der fachlichen Sachlichkeit leicht verändert.

getrennten anoxischen Zone erzeugt werden kann. Der Stickstoff wird durch vorgeschaltete Denitrifikation entzogen.

#### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion, in denen stickstoffhaltiges Abwasser anfällt.

#### Wirtschaftliche Aspekte

Moderate Kosten.

#### Beispielanlagen

Wird im Obst- und Gemüsesektor und im Stärkesektor eingesetzt.

#### Referenzliteratur

[31, VITO, et al., 2001, 65, Germany, 2002, 145, Metcalf & Eddy, 1991]

### 4.5.4.2 Ammoniakstrippung (T30)

#### Beschreibung

Neben den biologischen Verfahren gibt es noch eine Reihe physikalisch-chemischer Verfahren für die Reinigung von mit Stickstoff belasteten Abwasserströmen. In der Nahrungsmittelherstellung kann Kondensat, das stark mit Ammonium verunreinigt ist, in einem zweistufigen System von Ammoniak befreit werden. Das System besteht aus einer Desorptions- und einer Absorptionssäule, die beide mit Füllmaterial gefüllt sind, um die Kontaktfläche zwischen Abwasser und Luft zu erhöhen.

Die **Desorptionssäule** wird von oben mit dem alkalisierten Kondensat beaufschlagt, um das  $\text{NH}_4^+$ - $\text{NH}_3$ -Gleichgewicht in Richtung  $\text{NH}_3$  zu verschieben, das dann in der Kolonne abwärts fällt. Gleichzeitig wird an der Basis der Kolonne von unten Luft eingeblasen. Im Gegenstromverfahren erfolgt damit der Übergang von Ammoniak aus der wässrigen Phase in die gasförmige Phase.

Die mit Ammoniak angereicherte Luft wird dann in die **Absorptionskolonne** übergeleitet, wo eine Entfernung des Ammoniaks aus der Strippungsluft dadurch erfolgt, dass eine saure etwa 40 %ige Ammoniumsulfatlösung in der Desorptionssäule zirkuliert. Die von Ammoniak gereinigte Luft wird schließlich für die Strippung wiederverwendet.

Das Kondensat, das nach dem Strippverfahren einen geringen Ammoniumgehalt aufweist, wird teilweise als Brauchwasser wiederverwendet. Das überschüssige Kondensat wird in den aeroben biologischen Reinigungsprozess eingeleitet. Das Verfahren ist in Abbildung 4.40 zusammengefasst.

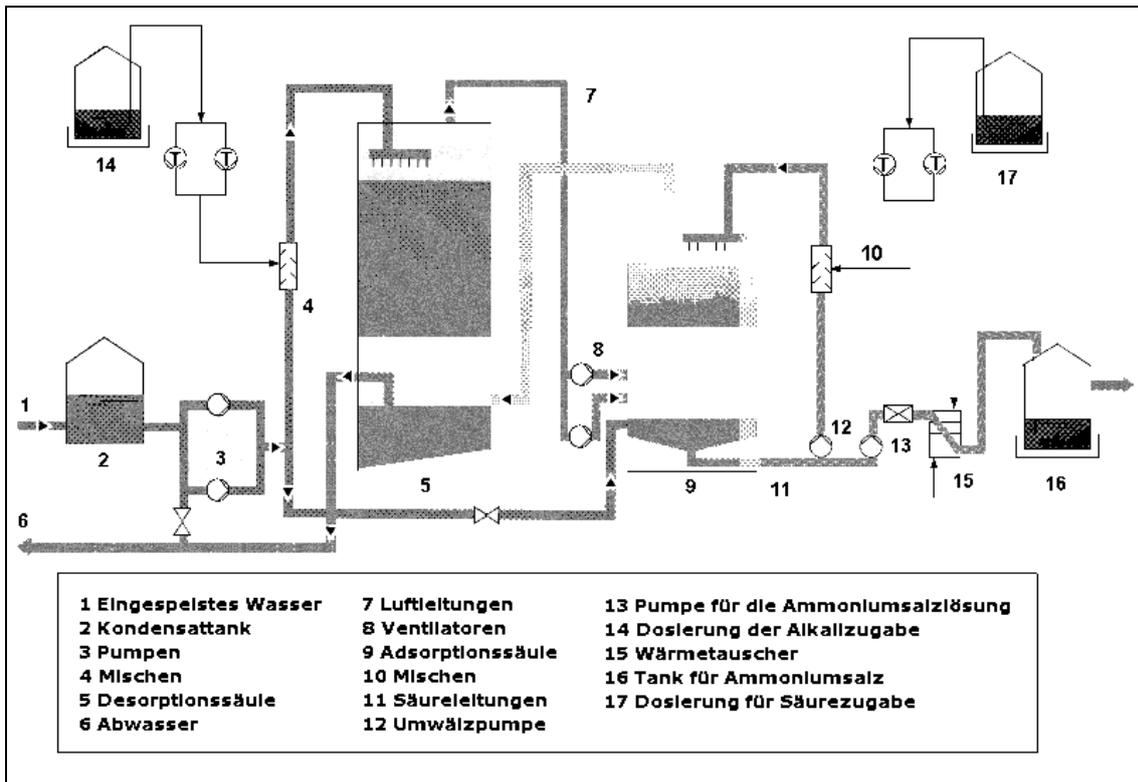


Abbildung 4.40: Das Verfahren der Ammoniakstrippung

Erreichbare Umweltvorteile

Geringerer Stickstoffgehalt. Es fällt weniger Abfall an, d. h. die bei diesem Verfahren entstehende Ammoniumsulfatlösung ((NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>) kann als Flüssigdünger oder proteinfreier Stickstofflieferant für das Futter von Wiederkäuern verwendet werden. Das Wasser, d. h. das Kondensat, das nur noch einen geringen Ammoniumgehalt aufweist, kann als Brauchwasser wiederverwendet werden.

Betriebsdaten

Ammoniumkonzentrationen von unter 2 mg/l können im abgegebenen Wasser erreicht werden. Dies entspricht einem Wirkungsgrad von etwa 99 %.

Tabelle 4.62 enthält Beispielparameter für die Ammoniakstrippung aus Kondensat, das im Zuckersektor anfällt.

| Parameter                                   | Einheit            | Wert    |
|---|--------------------|---------|
| Wasserdurchsatz                             | m <sup>3</sup> /h  | 400     |
| Ammoniakkonzentration im Kondensat          | mg/l               | 150     |
| Ammoniumkonzentration im Ablauf (bei 55 °C) | mg/l               | 1,7     |
| Luftbedarf                                  | Nm <sup>3</sup> /h | 320.000 |
| Energiebedarf                               | kW                 | 300     |

Tabelle 4.62: Parameter für die Ammoniakstrippung von Abwasser aus der Zuckerindustrie (Kondensat)

Anwendbarkeit

Technisch gesehen hat sich das Verfahren der Ammoniakstrippung für Abwasserströme mit hohen Ammoniakkonzentrationen bewährt.

Wirtschaftliche Aspekte

Sowohl das Kondensat, das nur noch geringe Ammoniummengen enthält, als auch die Ammoniumsulfatlösung können wiederverwendet werden.

Anlass für die Umsetzung

Die Ammoniakkonzentration im Abwasser wird normalerweise geregelt, da Ammoniak eine toxische Wirkung auf das Ökosystem des aufnehmenden Gewässers ausübt.

Referenzliteratur

[65, Germany, 2002]

**4.5.4.3 Biologische Phosphorentfernung (T31)**Beschreibung

Falls Reinigungsmittel mit phosphathaltigen Inhaltsstoffen eingesetzt werden, kann das Abwasser aus der Nahrungsmittelproduktion noch zusätzlich erhebliche Mengen an Phosphor enthalten. Mit Hilfe einer Vorbehandlung oder weitergehende Behandlung des Abwassers können 10 – 25 % des Phosphors, der in das System gelangt, entfernt werden. Falls ein weiterer Entzug notwendig ist, können auch gezielte weitergehende biologische Behandlungsverfahren eingesetzt werden. Diese Verfahren beruhen darauf, die Mikroorganismen im Schlamm unter Stress zu setzen, sodass sie mehr Phosphor aufnehmen, als sie für das normale Zellwachstum benötigen. In diesem Abschnitt werden zwei biologische Behandlungsverfahren zur Entfernung von Phosphor beschrieben.

Bei dem patentierten **A/O-Verfahren** zur Entfernung von Phosphor im Hauptstromverfahren erfolgt die Oxidation von Kohlenstoff in Kombination mit der Entfernung von Phosphor aus dem Abwasser. Dieses Verfahren ist ein Einstufensystem mit suspendierter Biomasse, das aus aufeinanderfolgenden anaeroben und aeroben Abschnitten besteht.

Für das patentierte **Phostrip-Verfahren**, d. h. die Entfernung von Phosphor im Nebenstromverfahren, durchläuft ein Teil des Rücklaufschlammes anaerobe Milieubedingungen in einem Phosphorstrippungsbecken.

Erreichbare Umweltvorteile

Geringere Phosphormengen sowie niedrigere BSB-/CSB-Werte.

Betriebsdaten

In Tabelle 4.63 ist die Effizienz verschiedener Behandlungsverfahren zur Entfernung von Phosphor zusammengefasst.

| <b>Behandlungsschritt oder -verfahren</b>              | <b>Entfernung des zufließenden Phosphors</b> |
|--|--|
|  | (%)  |
| Vorbehandlung  | 10 – 20                                      |
| Fällung (siehe Abschnitt 4.5.2.9).                     | 70 – 90                                      |
| Belebtschlamm (siehe Abschnitt 4.5.3.1.1)              | 10 – 25                                      |
| Tropfkörper (siehe Abschnitt 4.5.3.1.5)                | 8 – 12                                       |
| Rotationstauchkörper (RBC) (siehe Abschnitt 4.5.3.1.7) | 8 – 12                                       |
| <b>Biologische Phosphorentfernung</b>                  | <b>70 – 90</b>                               |
| Aktivkohleadsorption (siehe Abschnitt 4.5.4.4)         | 10 – 30                                      |
| Filtration (siehe Abschnitt 4.5.4.5)                   | 20 – 50                                      |
| Umkehrosiose (siehe Abschnitt 4.5.4.6)                 | 90 – 100                                     |

**Tabelle 4.63: Wirksamkeit verschiedener Abwasserbehandlungsverfahren zur Entfernung von Phosphor**

Angaben zufolge ist eine biologische Behandlung schwieriger zu handhaben als die Fällung.

Anwendbarkeit

Anwendbar in Anlagen der Nahrungsmittelproduktion, in denen phosphorhaltiges Abwasser anfällt.

Beispielanlagen

Wird im Obst- und Gemüsesektor eingesetzt.

### Referenzliteratur

[31, VITO, et al., 2001, 145, Metcalf & Eddy, 1991]

#### 4.5.4.4 Entfernung gefährlicher und prioritär gefährlicher Stoffe (T32)

##### Beschreibung

Abwasser kann organische Lösemittel, Rückstände von Pestiziden, toxisch organische Stoffe sowie toxisch anorganische Chemikalien enthalten. Die Richtlinie 76/464/EWG [206, EC, 1976] betreffend die Verschmutzung infolge der Ableitung bestimmter **gefährlicher Stoffe** in die Gewässer der Gemeinschaft beinhaltet eine Liste I der „besonders gefährlichen“ und eine Liste II der „weniger gefährlichen“ Stoffgruppen auf der Grundlage ihrer Toxizität, Langlebigkeit und Bioakkumulation. Die Richtlinie 2000/60/EG [207, EC, 2000] zur Wasserpolitik zielt auf die Eliminierung **prioritär gefährlicher Stoffe** ab. Diese Richtlinie besagt, dass die Verunreinigung durch Einleitung, Emission oder Verlust prioritär gefährlicher Stoffe gestoppt oder zeitlich begrenzt wird. Auf Vorschlag der Kommission haben das Europäische Parlament und der Rat sich bei den prioritären Stoffen auf Maßnahmen festgelegt, um die Verunreinigung von Gewässern durch diese Stoffe zu vermeiden.

Viele dieser Stoffe können durch angemessene Behandlungen wie Sedimentation (siehe Abschnitt 4.5.2.5), Fällung (siehe Abschnitt 4.5.2.9), Filtration (siehe Abschnitt 4.5.4.5) und Membranfiltration (siehe Abschnitt 4.5.4.6) entfernt werden. Mit Hilfe von einer nachsorgenden Behandlung des Abwassers wie Aktivkohle-adsorption und chemische Oxidation kann eine weitere Entfernung bewirkt werden.

Die **Aktivkohle-Adsorption** ist eine weiterführende Methode zur Behandlung von Abwasser. Mit körnigem Material (z. B. Sand) gefüllte Filter werden üblicherweise der Aktivkohleadsorption vorgeschaltet, um die löslichen organischen Stoffe zu entfernen, die mit den suspendierten Feststoffen im vorbehandelten Abwasser vorhanden sind. Die Aktivkohle kann als Granulat oder Pulver eingesetzt werden. Sie scheint eine geringe Affinität für niedermolekulare polare organische Stoffe zu haben. Aktivkohlegranulat adsorbiert die Schadstoffe an der Oberfläche und innerhalb der Granulatkügelchen. Diese Arten von Filtrationsmedien werden eingesetzt, um chemische Stoffe sowie Geruchs- und Geschmacksstoffe zu entfernen.

Die **chemische Oxidation** kann zur Entfernung von Ammoniak, zur Senkung der Konzentration organischer Reste und zur Reduzierung des Gehalts von Bakterien und Viren im Abwasser eingesetzt werden. Zu den Oxidationsmitteln gehören Chlor, Chlordioxid und Ozon.

##### Erreichbare Umweltvorteile

Geringere Gehalte an gefährlichen und prioritär gefährlichen Stoffen, BSB/CSB und Phosphor. Desinfektion des Abwassers, sofern eine chemische Oxidation stattgefunden hat.

##### Medienübergreifende Auswirkungen

Entstehung von Abfällen.

##### Betriebsdaten

Bei der **Aktivkohleadsorption** lagern sich die im einströmenden Abwasser befindlichen suspendierten Feststoffe an den Aktivkohlekörnchen ab. Dadurch tritt eine Verstärkung des Druckverlustes ein, die Strömung wird im Filter kanalisiert oder verstopft den Filter ganz. In diesem Fall geht Adsorptionsleistung verloren. Weiterhin können schwankende pH-Werte, Temperaturen und Strömungsgeschwindigkeiten die Leistungsfähigkeit der Aktivkohle beeinträchtigen.

Angaben zufolge liegt die Effizienz der Phosphorentfernung mittels Aktivkohleadsorption bei 10 – 30 %.

##### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion, deren Abwasser gefährliche oder prioritäre gefährliche Stoffe enthält.

##### Wirtschaftliche Aspekte

Hohe Energiekosten.

##### Anlass für die Umsetzung

Einhaltung gesetzlicher Vorschriften.

Beispielanlagen

Die Aktivkohlebehandlung wird im Fleischsektor, im Obst- und Gemüsesektor und im Getränkesektor eingesetzt.

Referenzliteratur

[31, VITO, et al., 2001, 145, Metcalf & Eddy, 1991, 206, EC, 1976, 207, EC, 2000]

**4.5.4.5 Filtration (T33)**Beschreibung

Als Reinigungsstufe zur Entfernung von Feststoffen aus dem Abwasser können Filtrationsverfahren, d. h. Langsamfiltration, Schnellfiltration, Tiefenfiltration, Oberflächenfiltration (Mikroscreening), Biofiltration und Koagulationsfiltration, eingesetzt werden. Im Gegensatz zur Sedimentation (siehe Abschnitt 4.5.2.5) oder der Entspannungsflotation (siehe Abschnitt 4.5.2.6) ist für eine Filtration keine Dichtedifferenz zwischen den Partikeln und der Flüssigkeit erforderlich. Die Trennung von Partikeln und Flüssigkeit beruht auf der Druckdifferenz zwischen der einen und der anderen Seite des Filters, sodass das Wasser durch den Filter hindurchtreten kann. Die Partikel werden dabei vom Filtermedium zurückgehalten.

Filter können entweder mittels Schwerkraft oder mit Druck funktionieren. Je nach Art der Feststoffe bieten sich **Standard-Sandfilter** oder **Filter mit zwei Medien** (Sand/Anthrazit) an. Es gibt inzwischen eine Reihe von kontinuierlich selbst reinigenden Sandfiltern, die sich für die Entfernung letzter suspendierter Feststoffe aus dem Abwasser nach der üblichen Nachklärung als äußerst wirkungsvoll erwiesen haben.

Erreichbare Umweltvorteile

Geringerer Gehalt an suspendierten Feststoffen und Phosphor.

Betriebsdaten

Aus der Brauwirtschaft wird über den Einsatz von Sandfiltern berichtet, mit denen strengere Abwasseranforderungen als 15 mg BSB<sub>5</sub> und 20 – 30 mg suspendierten Feststoffen pro Liter erreicht werden. In den Sandfiltern werden Reste suspendierter Feststoffe und der damit gekoppelte BSB entfernt. Der lösliche BSB ist nach einer weitergehenden aeroben Behandlung sehr gering.

Angaben zufolge liegt die Effizienz der Phosphorentfernung mittels Filtration bei 20 – 50 %.

Anwendbarkeit

Kann in allen Anlagen der Nahrungsmittelproduktion eingesetzt werden, um einen niedrigen Emissionsgrad für suspendierte Feststoffe zu erreichen.

Beispielanlagen

Wird in den Branchen Fleisch, Obst und Gemüse, Brauwirtschaft, Getränke und pflanzliche Öle und Fette eingesetzt.

Referenzliteratur

[1, CIAA, 2002, 13, Environment Agency of England and Wales, 2000, 65, Germany, 2002, 136, CBMC - The Brewers of Europe, 2002]

**4.5.4.6 Membranfiltration (T34)**Beschreibung

Bei Membranfiltrationsverfahren wird mit Druck und einer semipermeablen Membran eine selektive Auftrennung erreicht. Die Selektivität wird im Wesentlichen durch die Porengröße der Membran festgelegt. Falls ausgefällte Substanzen oder suspendiertes Material entfernt werden sollen, ist die Porengröße der Membran relativ groß. Eine sehr kleine Porengröße wird für die Entfernung anorganischer Salze oder organischer Moleküle gewählt. Während des Betriebs fließt der Zulauf über die Oberfläche der Membran, sauberes Wasser tritt durch die Membran hindurch, während die Schadstoffe und ein Teil des Zulaufs zurück bleiben. Das gereinigte oder behandelte Abwasser wird als „Permeat oder Produktwasserstrom“ bezeichnet, während die zurück gebliebene Lösung, die die Schadstoffe enthält „Konzentrat, Sole oder Retentat“ genannt wird.

Bei der **Cross-Flow-Mikrofiltration (CFM)** werden Membranen mit Porengrößen im Bereich von 0,1 – 1,0 µm eingesetzt. Der Zulauf muss vorher nicht einer intensiven Vorbehandlung unterzogen werden, da die Membran gegenüber Verschmutzung relativ widerstandsfähig ist und auch leicht gereinigt werden kann.

**Ultrafiltration (UF)** entspricht der Cross-Flow-Mikrofiltration mit dem Unterschied, dass UF-Membranen sehr kleine Poren in der Größenordnung von 0,001 bis 0,02 µm haben. Die UF-Membran mit der kleinsten Porengröße kann Moleküle mit einem Durchmesser über 1 nm oder einem Molekulargewicht von über 2.000 zurückhalten. Um eine Verschmutzung der Membran zu verhindern, kann eine Vorbehandlung erforderlich sein. Für die meisten UF-Anlagen wird die Zugabe von adsorbierenden Stoffen oder Flockungsmitteln in den Zustrom nicht empfohlen, da hierdurch das Membranmodul verstopft werden könnte.

Mit der **Umkehrosmosefiltration (RO)** können gelöste organische und anorganische Moleküle zurückgehalten werden. Wasser wird durch Filtration mit einer semipermeablen Membran von den gelösten Salzen getrennt, wobei der Druck über dem osmotischen Druck der Salze liegt. Der Vorteil der Umkehrosmose liegt darin, dass gelöste organische Stoffe weniger selektiv getrennt werden als mit anderen Verfahren. Das gereinigte Wasser tritt durch die Membran hindurch.

**Nanofiltration (NF)** ist eine relativ neue Technik, mit der die Eigenschaften der Ultrafiltration und der Umkehrosmose mit hoher Selektivität genutzt werden. Der Name kommt von der ungefähren Trenngrenze von einigen Nanometern oder genauer von Molekularmassen zwischen 200 und 1.000 g/mol. Dies wird mit Hilfe spezieller Nanofiltrationsmembranen erreicht, die zwar Poren einer bestimmten Größe haben, deren Rückhaltung jedoch auf der elektrostatischen Ladung der zu trennenden Moleküle beruht. Die Membranen haben eine selektive Permeabilität für Mineralstoffe, d. h. eine hohe Permeabilität für einwertige Kationen und Anionen und eine geringere Permeabilität für zweiwertige Kationen. Nanofiltrationssysteme werden mit mittleren Drücken im Bereich von 1 – 5 MPa betrieben.

**Elektrodialyse** erlaubt die Trennung von Ionen, indem statt einer hydraulischen Kraft ein elektrisches Feld als Triebkraft eingesetzt wird. Die verwendeten Membranen werden ionen-selektiv hergestellt (für Kationen und Anionen). Eine komplette Elektrodialyseeinheit besteht aus mehreren Zellen. Die chemische Fällung der Salze auf der Oberfläche der Membran und ein Verstopfen mit organischen Kolloidresten kann durch Vorbehandlung des Abwassers mit Aktivkohle oder chemischer Fällung oder durch eine Art Mehrfachmedium-Filtration verhindert werden.

### Erreichbare Umweltvorteile

Reduzierung des Gehalts an suspendierten und gelösten Feststoffen und Kolloiden. Auch der Phosphorgehalt kann verringert werden, z. B. durch Umkehrosmose. Aufkonzentrierung der Abwasserströme zwecks Volumenreduzierung vor weiterer Behandlung/Entsorgung, z. B. mögliche Aufkonzentrierung verdünnten Abfalls auf Konzentrationen, die eine Wiederverwendung möglich machen. Mögliche Rückgewinnung teurer Hilfs- oder Betriebsstoffe zur Wiederverwendung oder Rückgabe/Verkauf an Lieferanten am Standort oder außerhalb. Rückgewinnung von Zusatzstoffen/Materialien vor Ort. Rückgewinnung von Wasser zwecks Wiederverwendung.

### Medienübergreifende Auswirkungen

Es kann zusätzliches Abwasser entstehen.

### Betriebsdaten

Probleme können durch Verschmutzung der Membranen und durch Gelpolarisation entstehen. Da die Durchtrittsrate (Flux) durch die Membran relativ gering ist, wird eine große Membranfläche benötigt, um Stoffe rückzugewinnen.

Bei der Ultrafiltration können 90 – 95 % des Zustroms als Produktwasser rückgewonnen werden. Angaben zufolge liegt die Effizienz der Phosphorentfernung mittels Umkehrosmose bei 90 - 100 %.

Die Membranen in Umkehrosmoseeinheiten sind sehr empfindlich gegenüber Verschmutzung, sodass eine weitergehende Vorbehandlung erforderlich sein kann. Oxidationsmittel, die die Membranen und die Teilchen, die einen Film bilden oder sich ablagern, z. B. Öl, Fett oder andere Stoffe, angreifen, müssen in der Vorbehandlung entfernt werden, oder die Membran muss häufig gereinigt werden. Produktströme aus der Umkehrosmose haben normalerweise eine sehr hohe Qualität und eignen sich für die Wiederverwendung im Herstellungsprozess. Es ist standardmäßige Praxis, das Konzentrat zu entsorgen oder es einer entsprechenden

Behandlung zu unterziehen. Die Menge der rückgewonnenen Stoffe und der erforderliche Betriebsdruck hängen von der Art der gelösten Feststoffe und deren Konzentrationen ab.

#### Anwendbarkeit

Das Verfahren der kontinuierlichen Mikrofiltration (CMF) kann eingesetzt werden, um Bakterien und Schadstoffe aus dem Zulauf zu entfernen, eignet sich aber nicht für eine wirkungsvolle Pestizidbehandlung, sofern die Wirkstoffe relativ unlöslich sind oder an suspendiertem Material anhaften. In Großbritannien wird die kontinuierliche Mikrofiltration eingesetzt, um Schwermetalle aus Industrieabwässern zu entfernen.

Zu den Einsatzbereichen der Ultrafiltration zählt auch das Entfernen von Öl aus dem Abwasser und das Entfernen von trübungsverursachenden Farbstoffkolloiden. Aus dem Fischsektor wird vom Einsatz der Ultrafiltration zur Behandlung von Abwasser aus der Produktion von zerkleinertem Fischfleisch berichtet. Allerdings ist dieses Verfahren den Angaben zufolge nicht sehr kosteneffektiv bei der Trennung von Proteinen aus dem Abwasser der Fischmehlherstellung.

Umkehrosmose wird eingesetzt, um Schwermetalle und Pestizide, deren Wirkstoffe ein Molekulargewicht von über 200 haben, zu entfernen.

#### Wirtschaftliche Aspekte

Die Betriebskosten, die für den Gebrauch und die Reinigung der Membranen anfallen, können sehr hoch sein. Auch die Energiekosten sind hoch.

#### Beispielanlagen

Wird in den Branchen Fleisch, Fisch, Obst und Gemüse, Getränke und pflanzliche Öle und Fette eingesetzt.

#### Referenzliteratur

[13, Environment Agency of England and Wales, 2000, 87, Ullmann, 2001, 134, AWARENET, 2002, 145, Metcalf & Eddy, 1991]

### **4.5.4.7 Biologische nitrifizierende Filter (T35)**

Ammonium wird üblicherweise während der biologischen Behandlung entfernt, und zwar durch höheres Schlammalter (bzw. geringere Schlammbelastung), mit dem die Vermehrung nitrifizierender Bakterien erleichtert wird. Trotzdem ist es auch üblich, separate biologische nitrifizierende Filter als nachsorgende Behandlung des Abwassers zu installieren. Es handelt sich dabei gewöhnlich um standardmäßige Perkolationsfilter oder aerobe Hochleistungsfilter. Danach kann eine Belebtschlammanlage oder ein System mit sessilen Mikroorganismen oder Trägerbiologie folgen.

### **4.5.4.8 Desinfektion und Sterilisation (T36)**

Desinfektions- und Sterilisationsverfahren basieren auf demselben Grundprinzip. Sie schädigen die Zellstruktur der Bakterien und verhindern deren Vermehrung. In der Nahrungsmittelproduktion eingesetzte Desinfektionsmittel fallen in den Geltungsbereich der Richtlinie 98/8/EG [226, EC, 1998]. Die Bewertung der Auswirkungen von Wirkstoffen in Desinfektionsmitteln auf die Umwelt und die menschliche Gesundheit soll 2007 beginnen. Es können verschiedene Behandlungsarten durchgeführt werden. Dazu gehören der Gebrauch oxidierender Biozide, nichtoxidierender Biozide und UV-Bestrahlung. Dampf wird für die Desinfektion ebenfalls eingesetzt.

#### **4.5.4.8.1 Biozide Stoffe**

##### Beschreibung

**Mit Oxidierenden Bioziden** werden die Zellwände der Bakterien oxidiert, um deren Vermehrung zu verhindern. Dazu werden starke Oxidationsmittel wie Chlor/Brom, Ozon oder Wasserstoffperoxid benötigt. Die Verwendung chlorhaltiger Verbindungen wie z. B. Chlorgas, Chlordioxid, Natrium- oder Calciumhypochlorit hängt von der Bildung von Hypochlorsäure (das ist das wirksame Biozid) in wässrigen Lösungen ab. Biozide auf Brombasis herrschen in industriellen Anwendungsbereichen immer mehr vor, denn die Hypobromsäure dissoziiert bei einem höheren pH-Wert als die entsprechende Verbindung auf Chlorbasis.

**Ozon** kann aus der Luft oder aus reinem Sauerstoff erzeugt werden, wenn eine hohe Spannung zwischen eng beieinanderstehenden Elektroden angelegt wird. Ozon zerfällt nach der Erzeugung schnell, sodass keine

chemischen Reste im behandelten Abwasser zurückbleiben; nur der Anteil an gelöstem Sauerstoff ist hoch. Es werden keine Halogenverbindungen produziert. Ozon wird ebenfalls als Oxidationsmittel eingesetzt.

**Mit Nichtoxidierenden Bioziden** wird die Zellstruktur auf chemischem Wege verändert, um die Vermehrung der Bakterienzelle zu verhindern. Diese Stoffe werden in der Nahrungsmittelproduktion zunehmend eingesetzt, so zum Beispiel quarternäre Ammoniumsalze, Formaldehyd und Glutaraldehyd.

### Erreichbare Umweltvorteile

Wiederverwendung von Abwasser, sogar als Wasser mit Trinkwasserqualität.

### Medienübergreifende Auswirkungen

Wenn chlorhaltige Verbindungen verwendet werden, können im Abwasser vorhandene organische Verbindungen mit Chlor reagieren und toxische Stoffe wie Chloramine und andere organische Halogenverbindungen entstehen. Weiterhin kann diese Reaktion die Wirksamkeit des eingesetzten Chlors reduzieren. Chlor greift Materialien sehr aggressiv an, sogar Edelstahl. Die organischen Halogenverbindungen können eine biologische Abwasserbehandlung nach der Wiederverwendung des Wassers beeinträchtigen. Beim Einsatz von Ozon können sich karzinogene oder mutagene Verbindungen bilden. Ozon reizt die Atemwege, daher muss die Konzentration am Arbeitsplatz überwacht werden.

### Betriebsdaten

Eine Ozonbehandlung findet in tiefen und abgedeckten Kontaktkammern statt. Die Wirkung wird ohne weitere Chemikalien erreicht. Innerhalb weniger Stunden zerfällt Ozon auf natürliche Weise in Sauerstoff.

In der Fischverarbeitung wird Ozon eingesetzt, um eine Vielzahl von Abwasserströmen zu behandeln. Angaben zufolge ist es die effektivste Methode zur Behandlung verdünnter Abfälle. Bei höher konzentrierten Abwässern, z. B. aus der Verarbeitung von Tintenfisch, kann Ozon als Nachbehandlungsstufe eingesetzt werden.

### Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

### Wirtschaftliche Aspekte

Die Verwendung von Ozon ist mit erhöhten Kosten verbunden. Die Verwendung von Bioziden ist dagegen mit geringen Investitions- und Betriebskosten verbunden.

### Beispielanlagen

Wird in den Branchen Fleisch, Fisch, Obst und Gemüse und Getränke eingesetzt.

### Referenzliteratur

[1, CIAA, 2002, 13, Environment Agency of England and Wales, 2000, 17, Envirowise (UK) and March Consulting Group (UK), 1998, 66, EC, 1998, 134, AWARENET, 2002]

## 4.5.4.8.2 UV-Bestrahlung

### Beschreibung

**UV-Bestrahlung** ist wohl der bedeutendste Fortschritt bei den Desinfektionsverfahren in den vergangenen 10 Jahren. UV-Licht mit 254 nm wird schnell vom genetischen Material in den Bakterien- und Virenzellen aufgenommen und hindert die Zelle daran, sich zu vermehren. Die Dosierung wird in Milliwatt pro Quadratzentimeter, multipliziert mit der Kontaktdauer in Sekunden, angegeben. Die aktuelle Dosierung hängt von der Durchlässigkeit des Abwasserstroms ab, d. h. sie steht im Verhältnis zur Anwesenheit anderer Verbindungen, die UV-Licht absorbieren und damit seine Wirksamkeit verringern können.

### Erreichbare Umweltvorteile

Wiederverwendung von Abwasser, sogar als Wasser mit Trinkwasserqualität.

### Medienübergreifende Auswirkungen

Mit UV-Strahlen behandeltes Wasser kann leicht wieder infiziert werden; daher sollte es schnell und unter hygienischen Bedingungen verwendet werden.

Betriebsdaten

Im Vergleich zu anderen Verfahren liegt der Hauptvorteil der UV-Desinfektion darin, dass keine gefährlichen Chemikalien benötigt werden und gelagert werden müssen und dass sich keine schädlichen Nebenprodukte bilden. Ein großer Nachteil der UV-Desinfektion hingegen ist es, dass zwischen Lampe und Bakterium/Virus eine direkte Sichtlinie bestehen muss. Ein merklicher Gehalt an suspendierten Feststoffen oder eine Trübung (die die Durchlässigkeit herabsetzen) schützen das Bakterium und verhindern die Desinfektion. Abwässer, die Verbindungen mit hohen Durchgangswerten enthalten, benötigen höhere Dosen von UV-Strahlen. Ozon und UV-Strahlung sind instabil und können erst erzeugt werden, wenn sie benötigt werden.

Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar.

Wirtschaftliche Aspekte

Relativ geringe Investitions- und Betriebskosten.

Beispielanlagen

In den Branchen Fleisch, Fisch, Obst und Gemüse, Molkereien und Getränke einsetzbar.

Referenzliteratur

[1, CIAA, 2002, 13, Environment Agency of England and Wales, 2000, 66, EC, 1998, 134, AWARENET, 2002]

**4.5.5 Natürliche Behandlungen**

Wenn Wasser, Boden, Pflanzen, Mikroorganismen und die Atmosphäre untereinander reagieren, laufen in einer natürlichen Umgebung biologische und physikalisch-chemische Prozesse ab. Natürliche Behandlungsverfahren machen sich diese Prozesse zwecks Behandlung des Abwassers zunutze. Zu den entsprechenden Verfahren gehören viele, die auch bei der konventionellen Abwasserklärung eingesetzt werden, wie Sedimentation, Filtration, Fällung und chemische Oxidation. Allerdings laufen diese Verfahren mit „natürlicher“ Geschwindigkeit ab [145, Metcalf & Eddy, 1991]. Daher sind sie langsamer als konventionelle Verfahren. Die auf der Verwendung des Bodens basierenden Systeme nutzen den komplexen Reinigungsmechanismus des Bodens und die Aufnahme durch Pflanzen und andere Vegetation. In Systemen mit Wasser, z. B. natürlichen und künstlichen Feuchtgebieten und Systemen mit Wasserpflanzen, bildet die Vegetation eine Aufwuchsfläche, für Bakterien.

Natürliche Behandlungsverfahren<sup>29</sup> sind in einigen Mitgliedsstaaten gesetzlich verboten, da Bedenken hinsichtlich der Gefährdung des Grundwassers bestehen [182, Germany, 2003].

**4.5.5.1 Integrierte, künstlich geschaffene Feuchtgebiete (ICW) (T37)**Beschreibung

ICWs werden von anderen künstlich geschaffenen Feuchtgebieten dahingehend unterschieden, dass sie durch ihre Anlage in Bezug auf Boden, Wasser, Pflanzen- und Tierwelt der Ökologie natürlicher Feuchtgebiete so weit wie möglich entsprechen. Zusätzlich soll bei der Anlage der ICWs erreicht werden, dass diese in die Landschaft passen und eine Wiederherstellung/Schaffung von Habitaten möglich machen. Ein Schwerpunkt ist die Überwachung der Wasserqualität innerhalb der Feuchtgebiete und der Landflächen und Wasserläufe in ihrer Umgebung. Strategisch angelegte Überwachungsbrunnen werden regelmäßig geprüft.

Die Anlage eines ICW beinhaltet gleichzeitig die Vorbehandlung und die weitergehende Behandlung des Abwassers sowie nachfolgende Behandlungsstufen in einem Oberflächengewässer. Dies wird durch den Bau einer Reihe von verbundenen flachen Becken oder Teichen erreicht, die mit einer Vielfalt von Wasserpflanzen bepflanzt sind. Das Abwasser wird am höchsten Punkt dieser Teiche eingespeist und fließt im freien Gefälle durch alle Becken. Diese in Reihe angelegten Teiche sind in sich geschlossene, individuelle Ökosysteme. Mit jeder Stufe wird das Abwasser sauberer. Das Verhältnis des Abwasservolumens zur Fläche des Feuchtgebiets in der gesamten ICW-Anlage bestimmt die Qualität des am Ende ausfließenden Wassers.

<sup>29</sup> Anm. d. UBA-Bearb.: – ohne Vorbehandlung und Entfernung von Schadstoffen –

Die makrophytische Vegetation in der ICW-Anlage übernimmt eine Reihe von Aufgaben. Die wichtigste Aufgabe ist die Unterstützung der Biofilme (Schleimschichten), die im Feuchtgebiet die Hauptreinigung durchführen. Weiterhin erleichtert die Vegetation die Aufnahme von Nährstoffen und agiert als Filtermedium, und die entsprechend nachwachsende Vegetation wirkt gegen Geruch und pathogene Mikroorganismen. Durch die Vegetation werden die suspendierten Feststoffe filtriert und der hydraulische Widerstand erhöht – und damit auch die Verweildauer.

### Erreichbare Umweltvorteile

Die Mengen an suspendierten Feststoffen, Stickstoff und Phosphor und der BSB/CSB werden reduziert. Im Vergleich zur konventionellen Behandlung wird Energie eingespart. Verringerung der Emission von Treibhausgasen. Kein Einsatz chemischer Stoffe. Keine Schlammentsorgung erforderlich. Es gibt die Möglichkeit der Wiederverwertung von Nährstoffen, z. B. durch Kompostieren. Diese bilden die Lebensgrundlage für eine Vielzahl von Pflanzen und Tieren. [...] Die Fläche kann kultiviert werden.

### Medienübergreifende Auswirkungen

Das Grundwasser, das unterhalb der Feuchtgebiete fließt, hat einen geringeren Nährstoffgehalt als das umgebende Gelände. Phosphor bleibt im Boden zurück.

### Betriebsdaten

Eine Beispielanlage zur Käseherstellung in Irland produziert 85 t Käse am Tag aus 800.000 l Milch; dabei entstehen bis zu 1.300 m<sup>3</sup> Abwasser. Die Anlage verfügt über ein ICW von insgesamt 20 ha Größe, davon 8 ha Teiche, in dem 1,1 Mio. l Abwasser pro Tag behandelt werden. Das Abwasser wird in das etwa 800 m von der Molkerei entfernt liegende Feuchtgebiet gepumpt und dort am höchsten Punkt eingespeist. Das Teichsystem zieht sich entsprechend der Landschaftsform abwärts, und die Behandlung findet stufenweise statt, während das Abwasser durch das System fließt.

Die Leistungsdaten dieses ICWs sind in Tabelle 4.64 dargestellt.

| Probenentnahme              | CSB mg/l | Gesamtphosphor mg/l | Ammoniak mg/l | Nitrat mg/l |
|-----------------------------|----------|---------------------|---------------|-------------|
| Eingeleitetes Abwasser      | 3167     | 212                 | 12            | 102         |
| Letzter Überwachungsschacht | 36,5     | 0,5                 | 0,05          | <1          |

**Tabelle 4.64:** Gemeldete Leistungsdaten eines ICW

### Anwendbarkeit

Das ICW-Verfahren kann unter vielen Bedingungen eingesetzt werden, z. B. für gering oder hochbelastete Abwässer, und schwankende Abwassermengen. ICWs können als komplett neue Anlage oder als Teil eines bereits bestehenden Feuchtgebietes, eines vorhandenen Oberflächengewässers oder einer Kläranlage errichtet werden. Der Platzbedarf, der für ein ICW erforderlich ist, kann dessen Einsatz begrenzen, z. B. kann der Flächenverbrauch von 10 m<sup>2</sup> bis zu mehreren Hektar reichen, je nach Abwassermenge und Verschmutzungsgrad.

### Wirtschaftliche Aspekte

Angaben zufolge ermöglicht ein ICW im Vergleich zu einer konventionellen Anlage bei Betriebskosten, Abschreibung und Kapitalkosten Einsparungen von 0,03, 0,49 und 0,46 Euro pro kg CSB. Diese Einsparungen ergeben sich in erster Linie durch geringere Energiekosten sowie dadurch, dass keine Chemikalien gebraucht werden und kein Klärschlamm entsteht und gelagert bzw. entsorgt werden muss.

Die oben genannte Käserei berichtet, dass ihr ICW-System 120.000 Euro gekostet hat. Eine entsprechende konventionelle Anlage würde Angaben zufolge 3,175 Mio. Euro kosten.

### Anlass für die Umsetzung

Wirtschaftliche Einsparungen in der Beispielanlage.

### Beispielanlagen

Verschiedene Bauernhöfe, eine Käserei (Milchwirtschaft) und eine kommunale Kläranlage, alle in Irland.

Referenzliteratur

[204, Ireland, 2003]

#### 4.5.6 Klärschlammbehandlung

Dieser Abschnitt befasst sich mit der Behandlung von Klärschlamm. Techniken für die Verwertung oder Entsorgung von Klärschlämmen sind in diesem Dokument nicht enthalten. Die Wahl der Schlammbehandlung wird beeinflusst von den Verwertungs- und Entsorgungsmöglichkeiten, die dem Betreiber zur Verfügung stehen. Dazu gehören z. B. die Ausbringung auf Nutzflächen (siehe Abschnitt 4.1.6), die Entsorgung auf Mülldeponien, die Verwendung als Dichtmaterial, die Verbrennung, Mitverbrennung, Nass-Oxidation, Pyrolyse, Vergasung, Verglasung.

Die mit der Klärschlammbehandlung zusammenhängenden Kapital- und Betriebskosten können im Vergleich zu den Kosten der Abwasserbehandlung hoch sein und müssen daher zwecks Minimierung bereits zu einem frühen Zeitpunkt beim Entwurf der Anlage mit berücksichtigt werden. Umweltgesetze beschränken zunehmend die verfügbaren Entsorgungsmöglichkeiten oder erhöhen deren Kosten erheblich.

##### 4.5.6.1 Techniken der Klärschlammbehandlung

Mit Schlammbehandlungstechniken wird entweder das Volumen für die Entsorgung reduziert oder der Schlamm so verändert, dass er entsorgt oder anderweitig verwendet werden kann. Üblicherweise kann eine Volumenreduzierung durch Entwässerung vor Ort stattfinden, während eine weitere Behandlung des Schlamms gewöhnlich an anderer Stelle stattfindet. Durch die Verringerung des Volumens des für die Entsorgung vorgesehenen Schlamms reduzieren sich die Transportkosten und, sofern der Schlamm auf eine Mülldeponie verbracht wird, auch die Deponiekosten [13, Environment Agency of England and Wales, 2000]. Die Behandlungsverfahren, die in der Nahrungsmittelproduktion üblicherweise eingesetzt werden, werden nachfolgend beschrieben.

###### 4.5.6.1.1 Schlammkonditionierung (T38)

Beschreibung

Der Zweck der Konditionierung liegt in der Verbesserung der Eigenschaften des Schlamms, sodass er leichter einzudicken und/oder zu entwässern ist. Die normalerweise eingesetzten Techniken sind chemischer oder thermischer Natur. Eine chemische Konditionierung hilft bei der Abtrennung des gebundenen und eingeschlossenen Wassers vom Schlamm. Die thermische Konditionierung beinhaltet das kurzzeitige Erhitzen des Schlamms unter Druck.

Erreichbare Umweltvorteile

Reduzierung des Schlammvolumens.

Wirtschaftliche Aspekte

Die Kosten für Chemikalien sind in der Regel recht hoch.

Referenzliteratur

[145, Metcalf &amp; Eddy, 1991]

###### 4.5.6.1.2 Schlammstabilisierung (T39)

Beschreibung

Schlämme können mit Hilfe chemischer, thermischer, anaerober und aerober Prozesse stabilisiert werden, damit sie besser eingedickt und/oder entwässert werden können und Gerüche und pathogene Mikroorganismen reduziert werden.

Erreichbare Umweltvorteile

Verringerung übelriechender Inhaltsstoffe. Verringerung der Menge der biologisch abbaubaren Feststoffe im Schlamm. Verringerung der Menge der biologisch abbaubaren löslichen Anteile im Schlamm durch Umwand-

lung des mineralisierten Stickstoffs/organischer Bestandteile in Huminstoffe. Verringerung der pathogenen Mikroorganismen. Reduzierung des Fäulnispotenzials.

### Medienübergreifende Auswirkungen

Die thermische Stabilisierung erfordert große Mengen an Energie, und es können Gerüche freigesetzt werden. Eine aerobe Stabilisierung erfordert ebenfalls große Mengen an Energie zum Rühren und die Zufuhr von Sauerstoff.

### Betriebsdaten

Die technischen Anforderungen der chemischen Stabilisierung, mit der die nachfolgende Entwässerung verbessert und Geruch sowie pathogene Mikroorganismen reduziert werden können, sind gering. Der Feststoffanteil im Schlamm nimmt zu.

Eine thermische Stabilisierung erfordert wenig Platz und stellt eine wirkungsvolle Behandlung zur Entwässerung des Schlammes und zur Zerstörung von Bakterien dar. Ihre Anwendung kann davon abhängen, ob die benötigte Wärme natürlichen Ursprungs ist, als Nebenprodukt aus anderen Verfahren innerhalb der Anlage rückgewonnen wird oder direkt aus Energie erzeugt wird.

Bei einem aeroben Stabilisierungsverfahren, das relativ einfach betrieben werden kann, entsteht ein geruchloser Schlamm, aber das Verfahren wird erheblich von der Temperatur beeinflusst, und der Schlamm lässt sich schlecht mit mechanischen Verfahren entwässern.

In einem anaeroben Stabilisierungsprozess entsteht Gas, das als Energielieferant genutzt werden kann. Diese Technik bietet eine lange Verweilzeit und eine gute Mineralisierung des Schlammes.

### Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar, bei denen Klärschlamm anfällt.

### Wirtschaftliche Aspekte

Die Kapitalkosten für die thermische und die anaerobe Stabilisierung sind hoch. Eine aerobe Stabilisierung hat nur geringe Kapitalkosten.

### Referenzliteratur

[1, CIAA, 2002, 13, Environment Agency of England and Wales, 2000, 65, Germany, 2002, 145, Metcalf & Eddy, 1991]

#### **4.5.6.1.3 Schlammeindickung (T40)**

##### Beschreibung

Die Eindickung ist ein Verfahren zur Erhöhung des Feststoffanteils im Schlamm durch Entzug eines Teils der vorhandenen Flüssigkeit. Die zur Schlammeindickung in der Regel verwendeten Techniken umfassen Sedimentation, Zentrifugation und Entspannungsflotation. Das einfachste Eindickungsverfahren ist es, die Verfestigung des Schlammes in Sedimentationsbecken durchzuführen.

Der Schlamm kann sowohl nach der Vorbehandlung als auch nach der weitergehenden Behandlung des Abwassers eingedickt werden. Schlamm aus der Vorbehandlungsstufe besteht hauptsächlich aus anorganischem Material und/oder primären organischen Feststoffen. Sie können sich im Allgemeinen ohne chemische Zusätze absetzen und verdichten, da das entsprechende Wasser nicht zu sehr im Schlamm „eingeschlossen“ ist. Das Wasser im Schlamm aus der weitergehenden Behandlung des Abwassers ist innerhalb der Flocken gebunden und daher im Allgemeinen schwieriger zu entfernen.

##### Erreichbare Umweltvorteile

Reduzierung des Schlammvolumens.

##### Medienübergreifende Auswirkungen

Mögliche Geruchsemission bei der Entspannungsflotation. Hoher Energieverbrauch sowie Entstehung von Lärm und Vibrationen bei der Zentrifugation.

Betriebsdaten

Schlämme, die vom Boden der primären und sekundären Sedimentationsbecken abgezogen werden, haben einen Feststoffgehalt von 0,5 - 1,0 %. Bei Schlämmen aus der Entspannungsflotation beträgt der Feststoffgehalt bis zu 4 %.

Bei der Entspannungsflotation wird das System unter aeroben Bedingungen gehalten. Dabei sind Berichten zufolge Verstopfungen möglich.

Die Wirksamkeit des Eindickungsverfahrens durch Sedimentation ist abhängig von der Höhe der Schlammschicht und nicht von dem Volumen des Überstandes oberhalb des Schlammes. Aus diesem Grund ist ein enger, hoher Tank effektiver als ein niedriger Tank, der eine große Oberfläche bietet. Bei dieser Technik ist der Energieverbrauch gering.

Je nach Art der Entfernung des Primärschlammes kann der Einsatz von zwei Tanks erwogen werden; dann kann in dem einen die Sedimentation ungestört weitergehen, während der andere befüllt wird. Falls das nicht möglich ist, muss der Schlamm oben am Tank eintreten und möglichst über ein Prallblech geleitet werden, um hydraulische Störungen zu minimieren. Die Verweildauer im Tank ist abhängig von der Art des Schlammes. Eine zu große Verweilzeit sollte vermieden werden, damit die Möglichkeit des Auftretens anaerober Bedingungen mit den daraus folgenden Geruchs- und Korrosionsproblemen zu minimiert wird.

Innerhalb des Tanks muss eine leichte Bewegung möglich sein. Üblicherweise wird im Tank ein Krähwerk eingesetzt, um eine Schichtung des Schlammes zu verhindern und die Ableitung von eingeschlossenen Gasen und Wasser zu fördern. Ein herkömmliches Krähwerk kann den Schlamm je nach Art des Rohschlammes und insbesondere je nach relativem Anteil an Primärschlamm auf einen Feststoffgehalt von 4 – 8 % eindicken. Die Einspeiseraten in das Eindickbecken liegen bei 20 – 30 m<sup>3</sup> Schlammzulauf pro m<sup>2</sup> Oberfläche und Tag.

Zentrifugation ist eine gute Methode, um die Feststoffe zu entfernen, die sich durch Filtration nur schlecht abtrennen lassen. Zentrifugen benötigen wenig Platz und sind einfach zu installieren, erreichen allerdings nur eine geringe Feststoffkonzentration im Kuchen. Zudem haben sie einen hohen Energieverbrauch und können nur von ausgebildetem Personal gewartet werden.

Bei vielen Anlagen kann das Schlammvolumen durch Eindickung so reduziert werden, dass eine kosteneffektive Entsorgung außerhalb der Anlage möglich ist. Bei größeren Betrieben stellt das Eindicken die erste Stufe vor der weiteren Entwässerung dar.

Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar, bei denen Klärschlamm anfällt.

Wirtschaftliche Aspekte

Reduzierung der Pumpkosten in großen Kläranlagen. Das Eindicken mittels Sedimentation hat nur geringe Betriebskosten.

Anlass für die Umsetzung

Reduzierung der Leitungsgrößen und Pumpkosten in großen Kläranlagen.

Referenzliteratur

[1, CIAA, 2002, 13, Environment Agency of England and Wales, 2000, 65, Germany, 2002, 145, Metcalf & Eddy, 1991]

**4.5.6.1.4 Schlammmentwässerung (T41)**Beschreibung

Die Schlammmentwässerung dient demselben Zweck wie die Eindickung (siehe Abschnitt 4.5.6.1.3), aber der Feststoffgehalt liegt bei der Entwässerung viel höher. Es gibt eine Reihe von Verfahren zur Schlammmentwässerung. Die Auswahl des geeigneten Verfahrens ist abhängig von Art des zu entwässernden Schlammes sowie davon, was für ein Schlammkuchen entstehen soll. Allgemein werden zur Entwässerung Zentrifugen, Bandfilterpressen, Filterpressen und Vakuumfilter eingesetzt.

Erreichbare Umweltvorteile

Reduzierung des Schlammvolumens.

### Medienübergreifende Auswirkungen

Hoher Energieverbrauch sowie Entstehung von Lärm und Vibrationen bei der Zentrifugation, obwohl dies auch von der Geschwindigkeit und Intensität des einzelnen Verfahrens abhängig ist.

### Betriebsdaten

Zentrifugen sind kontinuierlich arbeitende Anlagen, die aus bestimmten Schlämmen einen Kuchen mit einem Feststoffgehalt von bis zu 40 % herstellen können. Aufgrund des „geschlossenen“ Aufbaus der Zentrifuge sind die damit zusammenhängenden Geruchsprobleme minimal. Außerdem können durch Zentrifugation schwer zu filtrierende Feststoffe gut abgeschieden werden. Zentrifugen benötigen nur wenig Platz und sind einfach zu installieren. Allerdings wird bei diesem Verfahren viel Energie verbraucht, die Feststoffmenge im Kuchen ist gering und für die Wartung ist ausgebildetes Personal erforderlich.

Filterpressen arbeiten diskontinuierlich und können manuell aufwendig sein. Die „Platten“ werden je nach Anwendung mit einem geeigneten Filtertuch bedeckt und der Schlamm durch die Öffnung in der Platte zugeführt. Der Schlamm wird unter Druck entwässert, während das Filtrat durch das Filtertuch hindurchtritt. Nach dem Wegnehmen des Drucks und der Trennung der Platten wird der Kuchen entweder manuell abgenommen oder in automatischen Prozessen durch Vibration entfernt. Eine Filterpresse kann einen Kuchen mit einem Feststoffgehalt von bis zu 40 % herstellen. Das gewonnene Filtrat hat nur einen geringen Anteil an suspendierten Feststoffen. Die Nachteile dieser Technik liegen darin, dass es sich um Chargenbetrieb handelt und die Filtertücher nur eine begrenzte Lebensdauer haben.

Bandpressen und Vakuumfilter sind kontinuierliche Verfahren, bei denen das Filtertuch über Walzen läuft, die den Schlamm mit Krafteinwirkung entwässern. Für die Optimierung der Leistung ist eine regelmäßige Wartung notwendig.

Eine Bandpresse kann einen Filterkuchen mit einem Feststoffanteil von bis zu 35 % erzeugen. Außerdem haben Bandpressen eine hohe Entwässerungseffizienz und sind relativ einfach zu warten. Zu den Nachteilen gehören hydraulische Einschränkungen, eine kurze Lebensdauer und eine gewisse Empfindlichkeit gegenüber den Eigenschaften des eingespeisten Schlamms.

Vakuumfilter sind komplexe Systeme mit einem maximalen Differentialdruck von 1 bar. Das Filtrat kann einen hohen Anteil an Feststoffen aufweisen.

### Anwendbarkeit

In allen Anlagen der Nahrungsmittelproduktion anwendbar, bei denen Klärschlamm anfällt.

### Wirtschaftliche Aspekte

Das Pumpen von Schlamm mit einem Feststoffanteil von über 10 % ist schwierig und teuer. Im Zuge einer Entwässerung wird ein Schlammkuchen produziert, der einen Feststoffgehalt von 20 bis 50 % aufweist. Mit geringerem Wassergehalt vermindern sich auch die Entsorgungskosten. Filterpressen verursachen hohe Kosten für Arbeitskräfte. Vakuumfilter haben hohe Betriebs- und Wartungskosten.

### Anlass für die Umsetzung

Verringerung der Kosten für die Entsorgung.

### Referenzliteratur

[1, CIAA, 2002, 65, Germany, 2002, 199, Finland, 2003]

#### **4.5.6.1.5 Schlamm Trocknung (T42)**

##### Beschreibung

Die Schlamm Trocknung ist ein Verfahren, bei dem der Wassergehalt durch Verdunstung in die Luft verringert wird. Zweck der Trocknung ist die Entfernung von Feuchtigkeit aus dem Nassschlamm, sodass dieser effizient verwendet oder entsorgt werden kann.

##### Erreichbare Umweltvorteile

Reduzierung des Schlammvolumens.

### Betriebsdaten

Der Feuchtigkeitsgehalt des Trockenschlammes kann bis zu 10 % betragen. Die Trocknung geschieht – sofern es die lokalen Wetter- und Klimabedingungen erlauben – durch natürliche Verdunstung oder ansonsten durch Rückgewinnung von Wärme, die in der Anlage anfällt, oder durch direkten Verbrauch von Energie.

### Referenzliteratur

[145, Metcalf & Eddy, 1991]

## **4.5.7 Abwasserbehandlung in verschiedenen Bereichen**

Dieser Abschnitt informiert über die Behandlung von Abwasser in bestimmten Branchen und über einzelne Prozesse innerhalb dieser Branchen.

### **4.5.7.1 Fleisch und Geflügel**

#### **4.5.7.1.1 Abwasserbehandlung**

Abwasser aus der Fleischverarbeitung wird mit Hilfe der folgenden Vorbehandlungsverfahren behandelt:

- Sieben (siehe Abschnitt 4.5.2.1)
- Fettabscheidung (siehe Abschnitt 4.5.2.2)
- Ausgleichsverfahren für Durchfluss und Schmutzfracht (siehe Abschnitt 4.5.2.3)
- Entspannungsflotation (siehe Abschnitt 4.5.2.6)
- Havariebecken (siehe Abschnitt 4.5.2.7)

Nach der Vorbehandlung kann eine weitergehende Behandlung des Abwassers am Standort erforderlich sein, um die notwendige Abwasserqualität zu erreichen oder die Kosten für eine Abwasserbehandlung z. B. in einer kommunalen Kläranlage zu minimieren. Für Abwasserströme mit einem BSB von über 1.000 – 1.500 mg/l können anaerobe Behandlungsverfahren eingesetzt werden (siehe Abschnitt 4.5.3.2). Das Abwasser aus dem anaeroben Verfahren kann möglicherweise nach einer Oberflächenbelüftung abgegeben werden. Bei geringer belasteten Abwasserströmen erfolgt eine aerobe Behandlung (siehe Abschnitt 4.5.3.1). Mit einem zweistufigen biologischen System (siehe Abschnitt 4.5.3.3.2), wobei ein aerobes Verfahren dem anaeroben folgt, kann das Abwasser eine Qualität erreichen, dass es für die Einleitung in ein Gewässer geeignet ist.

Falls der genehmigte Grenzwert für abfiltrierbare Stoffe niedrig liegt, kann eine nachsorgende Behandlung des Abwassers notwendig werden (siehe Abschnitt 4.5.4). Soll das behandelte Abwasser ganz oder teilweise in der Produktion als Wasser mit Trinkwasserqualität wiederverwendet werden, ist eine nachsorgende Behandlung des Abwassers, die eine Sterilisation und Desinfektion mit einschließt, unumgänglich.

Abbildung 4.41 zeigt eine schematische Darstellung einer in der Fleisch- und Geflügelverarbeitung üblichen Abwasserbehandlung.

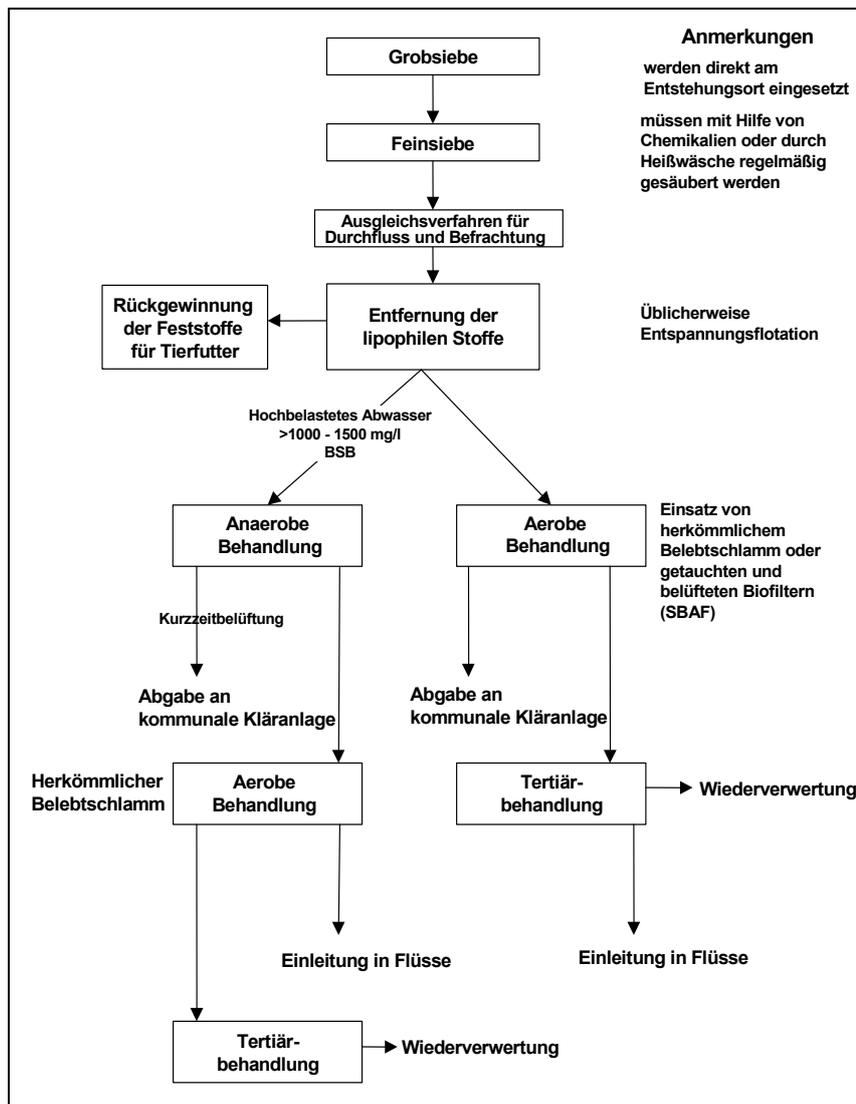


Abbildung 4.41: Fließbild der Behandlung von Abwasser aus der Verarbeitung von Fleisch und Geflügel [13, Environment Agency of England and Wales, 2000]

## 4.5.7.2 Fisch und Schalentiere

### 4.5.7.2.1 Eigenschaften des Abwassers

Das bei der Fischverarbeitung anfallende Abwasser entsteht beim Umgang mit dem Rohmaterial und seiner Lagerung, beim Schwimmen der Fische und Innereien in Rinnen, beim Auftauen und bei der Reinigung von Geräten und Fußböden. Im Bereich der Konservenherstellung entsteht Abwasser beim Spülen der Dosen und bei der Beseitigung von verschütteten Laken, Saucen und Ölen. Alle diese Abwässer müssen vor der Einleitung in einer Kläranlage behandelt werden. Andernfalls können die Abwässer in den aufnehmenden Gewässern Sauerstoffmangel und Euthrophie verursachen.

### 4.5.7.2.2 Abwasserbehandlung

Die Vorbehandlung von Abwasser aus der Fischverarbeitung umfasst folgende Verfahren:

- Sieben/Rechen (siehe Abschnitt 4.5.2.1)
- Sedimentation (siehe Abschnitt 4.5.2.5)
- Entspannungsfлотation (siehe Abschnitt 4.5.2.6)
- Zentrifugation (siehe Abschnitt 4.5.2.8)
- Fällung (siehe Abschnitt 4.5.2.9).

In Tabelle 4.65 sind die Eigenschaften von unbehandeltem Abwasser aus der Fischverarbeitung und die Wirksamkeit der Vorbehandlungen angegeben.

| Behandlungsmethode  | BSB <sub>5</sub><br>(mg/l) | Gesamtstickstoff<br>(mg/l) | Gesamtphosphor<br>mg/l | Lipophile<br>Stoffe<br>(mg/l) |
|---|----------------------------|----------------------------|------------------------|-------------------------------|
| Ohne Behandlung   | 2.000 – 28.000             | 400 – 1.000                | 80 – 150               | 500 – 25.000                  |
| Zentrifugation  | 1.500 – 5.000              | –                          | –                      | 500 – 2.000                   |
| Entspannungsflotation   | 1.500 – 6.000              | 200 – 600                  | 40 – 90                | 400 – 2.000                   |
| Fällung (H <sub>2</sub> SO <sub>4</sub> ) und<br>Entspannungsflotation            | 800 – 3.000                | 150 – 300                  | 30 – 50                | 100 – 500                     |
| Fällung (Fe/Mo) und<br>Polyelektrolyt   | 600 – 3.000                | 150 – 300                  | 5 – 10                 | 100 – 500                     |
| Zweistufige<br>Entspannungsflotation mit<br>Fällung (Fe/Mo) und<br>Polyelektrolyt | 500 – 1.500                | 100 – 200                  | 5 – 10                 | 50 – 300                      |

**Tabelle 4.65:** Eigenschaften von unbehandeltem Abwasser aus der fischverarbeitenden Industrie und Effizienz von Vorbehandlungen  
[134, AWARENET, 2002]

Sofern die Abwasserqualität nach der Vorbehandlung noch nicht für die Einleitung in eine kommunale Kläranlage geeignet ist, muss eine weitergehende Behandlung des Abwassers erfolgen. Für Abwasser mit einem BSB/CSB von <3.000 mg/l hat eine aerobe Behandlung eine hohe Effizienz (siehe Abschnitt 4.5.3.1). Für hoch belastetes Abwasser, z. B. mit einem BSB/CSB von >3.000 mg/l, wird eine anaerobe Behandlung eingesetzt (siehe Abschnitt 4.5.3.2).

Zu den nachsorgenden Behandlungen des Abwassers in der Fischverarbeitung gehören z. B. Membrantrennverfahren (siehe Abschnitt 4.5.4.6) sowie Desinfektion und Sterilisation (siehe Abschnitt 4.5.4.8).

Auch über die Abwasserlandbehandlung wird aus diesem Sektor berichtet (siehe Abschnitt 4.1.6).

### 4.5.7.3 Obst und Gemüse

#### 4.5.7.3.1 Eigenschaften des Abwassers

Bei der Verarbeitung von Obst und Gemüse fallen große Abwassermengen z. B. beim Schälen und Blanchieren an, die in der Regel hoch mit organischen Stoffen belastet sind, oder die Reinigungsmittel, ggf. Desinfektionsmittel wie Chloride, Erdreste, suspendierte Feststoffe wie z. B. Pflanzenfasern, gelöste Stoffe, Salze, Nährstoffe und pflanzliche Pathogene enthalten. Das Abwasser kann auch Reste von Pestiziden und Fungiziden vom Waschen der Rohware enthalten. Andere Parameter, die bei der Behandlung des Abwassers berücksichtigt werden müssen, sind der pH-Wert, die Temperatur und die Anwesenheit von Salzen. Die Eigenschaften des Abwassers hängen von verschiedenen Faktoren ab, z. B. von

- der Qualität des Zulaufs und des Wasserverbrauchs der Art der verarbeiteten Rohware und der Art der Verarbeitung, z. B. Schälen, Blanchieren, in Konserven abfüllen
- dem Zustand der Rohware, z. B. Beschädigungen, Reifegrad
- saisonalen Schwankungen
- der Art der verwendeten Maschinen und Geräte
- der Art des Transports der Produkte, nass oder trocken
- den Reinigungsverfahren und der Art der verwendeten Reinigungsmittel.

Die bedeutendsten Verunreinigungen im Obst- und Gemüsesektor sind die organische Belastung und die suspendierten Feststoffe. Weiterhin kann die Messung von Pestiziden erforderlich sein, um die lokalen gesetzlichen Vorschriften einhalten zu können. Für die USA gilt, dass bei einem Gehalt von mehr als 0,05 mg/l Maßnahmen erforderlich sind.

### 4.5.7.3.2 Abwasserbehandlung

Die folgenden Behandlungsmöglichkeiten sind nicht unbedingt auf die Verarbeitung von Kartoffeln anwendbar. Besondere Eigenschaften siehe Abschnitt 4.5.7.3.6.

Vor der Behandlung des Abwassers werden im Obst- und Gemüsesektor die Abwasserströme üblicherweise getrennt (siehe Abschnitt 4.7.3.7). Nach der Trennung findet die Vorbehandlung statt, für die folgende Verfahren eingesetzt werden:

- Sieben/Rechen (siehe Abschnitt 4.5.2.1)
- Ausgleichsverfahren für Durchfluss und Abwasserbelastung (siehe Abschnitt 4.5.2.3)
- Neutralisation (siehe Abschnitt 4.5.2.4)
- Sedimentation (siehe Abschnitt 4.5.2.5)
- Entspannungsflotation (siehe Abschnitt 4.5.2.6)
- Zentrifugation (siehe Abschnitt 4.5.2.8)
- Fällung (siehe Abschnitt 4.5.2.9).

Suspendierte Feststoffe und Erde werden besser mittels Sedimentation als durch Entspannungsflotation getrennt. Falls jedoch das Abwasser erhebliche Mengen lipophiler Stoffe enthält, wird üblicherweise eine Kombination aus Sedimentation und Entspannungsflotation eingesetzt.

Bei Abwässern aus Schälvorgängen kann der Einsatz von Chemikalien die ernährungsphysiologische Nutzung der abgetrennten Schälmasse einschränken. Falls die Schälmasse zur Ernährung eingesetzt werden soll, ist eine getrennte Abwasserbehandlung notwendig. Anlagen zum Dampfschälen können getrennte Prozesslinien haben.

Nach der Vorbehandlung kann das Abwasser an eine kommunale Kläranlage abgegeben werden. Eine weitergehende Behandlung des Abwassers wird erforderlich, wenn das Abwasser in Oberflächengewässer eingeleitet werden oder eine Qualität erreichen soll, die eine Wiederverwendung möglich macht. Aufgrund des Saisonbetriebs kann die biologische Behandlung von Abwasser aus der Obst- und Gemüseverarbeitung für die Betreiber zu einem Problem werden.

Für Abwasserströme mit einem BSB von über 1.000 – 1.500 mg/l können anaerobe Behandlungsverfahren eingesetzt werden (siehe Abschnitt 4.5.3.2). Nach dieser Behandlung und einer Oberflächenbelüftung kann das Abwasser zwar an eine kommunale Kläranlage, aber nicht in Oberflächengewässer abgegeben werden. Für geringer belastete Abwasserströme reicht eine aerobe Behandlung (siehe Abschnitt 4.5.3.1). Das Abwasser aus dem Obst- und Gemüsesektor enthält häufig wenig Stickstoff und Phosphor, sodass zur Unterstützung einer ausreichenden biologischen Aktivität diese Nährstoffe zugesetzt werden müssen. Nitrifikations- und Phosphoreliminationsprozesse können durch kontrollierte Belüftung unterstützt werden. Mit einem zweistufigen biologischen System (siehe Abschnitt 4.5.3.3.2), wobei ein aerobes Verfahren dem anaeroben folgt, kann das Abwasser eine solche Qualität erreichen, dass es für die Einleitung in ein Gewässer geeignet ist.

Falls strengere Anforderungen bezüglich des aufnehmenden Gewässers bestehen oder falls das Wasser innerhalb des Betriebes wiederverwendet werden soll, ist eine nachsorgende Behandlung des Abwassers nötig (siehe Abschnitt 4.5.4). Soll das behandelte Abwasser ganz oder teilweise z. B. in der Produktion als Wasser mit Trinkwasserqualität wieder verwendet werden, ist eine nachsorgende Behandlung des Abwassers, die eine Sterilisation und Desinfektion mit einschließt, unumgänglich.

Abbildung 4.42 zeigt das Fließbild für im Obst- und Gemüsesektor übliche Abwasserbehandlungsverfahren.

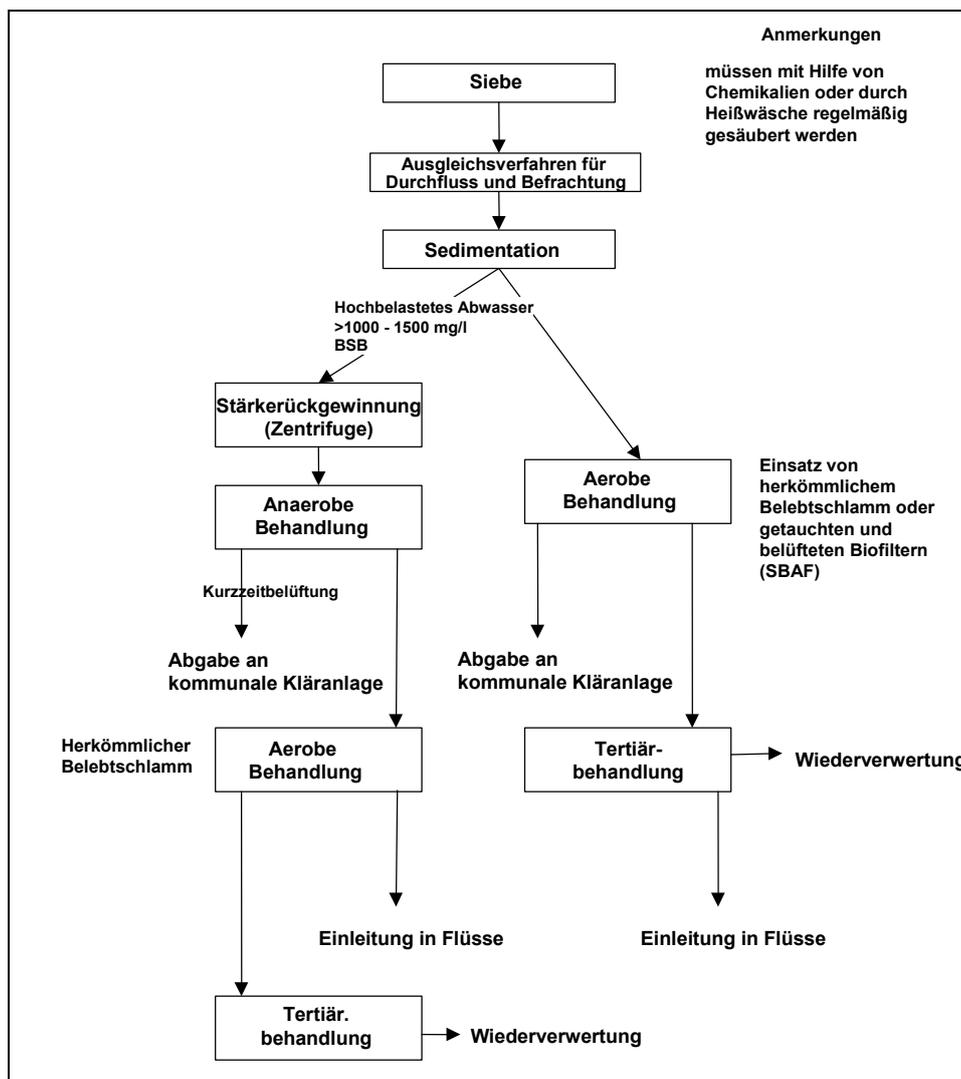


Abbildung 4.42: Fließbild einer im Obst- und Gemüsektor üblichen Abwasserbehandlung [13, Environment Agency of England and Wales, 2000]

Tabelle 4.66 zeigt einige kombinierte Abwasserbehandlungsverfahren, die aus dem Obst- und Gemüsektor gemeldet werden.

| Kombination der Verfahren   |
|---|
| Vorbehandlungen (siehe Abschnitt 4.5.2)   |
| Vorbehandlungen (siehe Abschnitt 4.5.2) + aerobe Verfahren (siehe Abschnitt 4.5.3.1)  |
| Vorbehandlungen (siehe Abschnitt 4.5.2) + anaerobe Verfahren (siehe Abschnitt 4.5.3.2) + aerobe Verfahren (siehe Abschnitt [4.5.3.1])   |
| Vorbehandlungen (siehe Abschnitt 4.5.2) + anaerobe Verfahren (siehe Abschnitt 4.5.3.2) + aerobe Verfahren (siehe Abschnitt 4.5.3.1) + biologische Nitrifikation/Denitrifikation (siehe Abschnitt 4.5.4.1) + biologische Methoden zur Entfernung von Phosphor (siehe Abschnitt 4.5.4.3)  |
| Vorbehandlungen (siehe Abschnitt 4.5.2) + anaerobe Verfahren (siehe Abschnitt 4.5.3.2) + aerobe Verfahren (siehe Abschnitt 4.5.3.1) + biologische Nitrifikation/Denitrifikation (siehe Abschnitt 4.5.4.1) + biologische Methoden zur Entfernung von Phosphor (siehe Abschnitt 4.5.4.3) + Fällung (siehe Abschnitt 4.5.2.9) + Filtration (siehe Abschnitt 4.5.4.5) |

| Kombination der Verfahren   |
|---|
| Vorbehandlungen (siehe Abschnitt 4.5.2) + anaerobe Verfahren (siehe Abschnitt 4.5.3.2) + aerobe Verfahren (siehe Abschnitt 4.5.3.1) + biologische Nitrifikation/Denitrifikation (siehe Abschnitt 4.5.4.1) + biologische Methoden zur Entfernung von Phosphor (siehe Abschnitt 4.5.4.3) + Fällung (siehe Abschnitt 4.5.2.9) + Filtration (siehe Abschnitt 4.5.4.5) + Aktivkohleadsorption (siehe Abschnitt 4.5.4.4)  |
| Vorbehandlungen (siehe Abschnitt 4.5.2) + anaerobe Verfahren (siehe Abschnitt 4.5.3.2) + aerobe Verfahren (siehe Abschnitt 4.5.3.1) + biologische Nitrifikation/Denitrifikation (siehe Abschnitt 4.5.4.1) + biologische Methoden zur Entfernung von Phosphor (siehe Abschnitt 4.5.4.3) + Fällung (siehe Abschnitt 4.5.2.9) + Filtration (siehe Abschnitt 4.5.4.5) + Aktivkohleadsorption (siehe Abschnitt 4.5.4.4 + Membrantrennverfahren, d. h. Querstrom-Mikrofiltration) (siehe Abschnitt 4.5.4.6) |
| Vorbehandlungen (siehe Abschnitt 4.5.2) + anaerobe Verfahren (siehe Abschnitt 4.5.3.2) + aerobe Verfahren (siehe Abschnitt 4.5.3.1) + biologische Nitrifikation/Denitrifikation (siehe Abschnitt 4.5.4.1) + biologische Methoden zur Entfernung von Phosphor (siehe Abschnitt 4.5.4.3) + Fällung (siehe Abschnitt 4.5.2.9) + Filtration (siehe Abschnitt 4.5.4.5) + Aktivkohleadsorption (siehe Abschnitt 4.5.4.4 + Membrantrennverfahren, d. h. Umkehrosmose (siehe Abschnitt 4.5.4.6)               |

**Tabelle 4.66: Kombinierte Abwasserbehandlungsverfahren, die aus dem Obst- und Gemüsesektor gemeldet werden [31, VITO, et al., 2001]**

#### 4.5.7.3.3 Wasserrückgewinnung in einem gemüseverarbeitenden Betrieb – Fallstudie

##### Beschreibung

In einem gemüseverarbeitenden Betrieb wurden folgende wassersparende Verfahren eingesetzt, weil zu wenig Grundwasser vorhanden war und alternative Wasserquellen, z. B. Oberflächenwasser, fehlten und Trinkwasser zu teuer war:

- Wiederverwendung des behandelten Abwassers für Betriebsverfahren, bei denen keine Trinkwasserqualität erforderlich war. Die aerobe Behandlung des Abwassers wurde durch eine Reinigungsstufe, d. h. Sandfiltration, ergänzt. Damit wurde eine Verringerung des spezifischen Wasserverbrauchs um 3 – 3,5 m<sup>3</sup> pro Tonne Produkt erreicht
- Reduzierung des Salzgehaltes im Abwasser durch Dampfstrippung
- Aufstockung der Kapazität zur aeroben Behandlung des Abwassers und Einsatz einer anaeroben Vorbehandlung.

##### Erreichbare Umweltvorteile

Geringerer Verbrauch von Wasserressourcen, Wiederverwendung von Abwasser und Reduzierung der Schadstoffbelastung des Wassers.

##### Medienübergreifende Auswirkungen

Hoher Energiebedarf für die Abwasserbehandlung.

##### Betriebsdaten

Die Anlage erhöhte ihre Produktionsleistung innerhalb von zehn Jahren von 17.000 auf 55.000 t/Jahr. Ziel war der Ersatz von mindestens 50 % des Rohwasserbedarfs und damit die Senkung des spezifischen Wasserverbrauchs auf unter 2 m<sup>3</sup>/t Produkt.

Die Abwasserbehandlung am Standort besteht aus einer anaeroben Vorbehandlung (Reaktorvolumen 5.000 m<sup>3</sup>, Befrachtung 30 t CSB/Tag und spezifische Befrachtung 6 kg CSB/m<sup>3</sup>/Tag) und einer nachfolgenden aeroben Belebtschlammanlage. Nach der Sedimentation wird das Abwasser in einer zweistufigen Sandfiltration mit einer maximalen Kapazität von 100 m<sup>3</sup>/h behandelt. Nach der Einstellung des pH-Werts und/oder dem Zusatz von Flockungsmitteln wird das Wasser in eine Ultrafiltrationseinheit geleitet, die eine Kapazität von 40 m<sup>3</sup>/h hat. Die Ultrafiltrationseinheit wird unter geringem Druck betrieben (0,5 – 1 bar) und besteht aus Hohlfasermembranen. Zum Schluss wird das Wasser in einem zweistufigen Umkehrosmoseverfahren behandelt. Das Retentat aus der ersten Stufe wird in die zweite Stufe eingespeist. Die Umkehrosmoseeinheit hat eine Kapazität von 20 m<sup>3</sup>/h, einen Betriebsdruck von 8 – 10 bar und einen Wirkungsgrad von 70 %. Obwohl das gewonnene

Wasser frei von Salzen und Bakterien ist, wird es noch einmal mit UV-Bestrahlung sterilisiert. Das Spülwasser aus den Sandfiltern und der Ultrafiltration wird für die biologische Behandlung wiederverwertet.

In Tabelle 4.67 sind übliche Parameter der Qualität des Abwassers in den unterschiedlichen Behandlungsstufen im Vergleich zu frischem Grundwasser angegeben.

| Parameter                                  | Einheit              | Abwasser | Nach biologischer Behandlung | Nach Feinfiltration | Nach Sterilisation | Grundwasser | Prozesswasser* |
|--|----------------------|----------|------------------------------|---------------------|--------------------|-------------|----------------|
| CSB  | mg O <sub>2</sub> /l | 12.000   | 114                          |                     | 0                  | 0           |                |
| pH-Wert                                    |                      | 8,5      | 8,3                          | 8,2                 | 5,5                | 8,3         | 7              |
| Trübung                                    | NTU                  |          | 16                           | 4,3                 | 0                  |             | 0              |
| Gesamtphosphor                             | mg/l                 |          | 34                           | 34                  | <0,5               | <0,5        | <0,5           |
| Leitfähigkeit                              | mS/cm                | 4,3      | 4,3                          | 4,2                 | 0,15               | 2,6         | 1,4            |
| Ammoniak-N (NH <sub>4</sub> <sup>+</sup> ) | mg/l                 |          | <2                           | <2                  | <2                 | 0,17        |                |
| Eisen                                      | mg/l                 |          |                              |                     | 0,03               | 0,23        | 0,1            |
| Härte                                      | mmol/l               |          | 1,0                          | 1,0                 | <0,3               | <0,3        | <0,3           |
| Bikarbonat                                 | G/l                  |          | 2,9                          | 2,9                 | <0,3               | <0,1        | <0,2           |
| Keimzahl (KBE)                             | i/ml                 |          |                              |                     | 0                  | 0           | 0              |
| <i>E. coli</i>                             | i/ml                 |          |                              |                     | 0                  | 0           | 0              |

\* Mischung aus Grundwasser und sterilisiertem Wasser im Verhältnis 1:1

**Tabelle 4.67: Qualitätsparameter für behandeltes Abwasser, Rohwasser und Prozesswasser**

#### Wirtschaftliche Aspekte

Die Kosten für Trinkwasser schwankten zwischen 0,99 und 1,54 Euro/m<sup>3</sup>, und ein Anstieg war aufgrund der großen Nachfrage zu erwarten. Die Kosten für das Prozesswasser lagen bei 1,03 Euro/m<sup>3</sup>.

#### Anlässe für die Umsetzung

Das Unternehmen verwendete Grundwasser, da es bakteriologisch einwandfrei war. Es gab jedoch einige Schwierigkeiten, zum Beispiel

- musste das Grundwasser aus einer Tiefe von 300 m entnommen werden
- fiel der Grundwasserspiegel vor Ort und führte damit zur Verknappung
- entsprachen die im Grundwasser enthaltenen Salzmengen und einige andere Parameter nicht den Qualitätsstandards. Tabelle 4.68 enthält Beispielparameter im Vergleich mit den Richtwerten der Weltgesundheitsorganisation (WHO).

| Parameter     | Einheit | Grundwasser | WHO-Richtwerte |
|---------------|---------|-------------|----------------|
| pH-Wert       |         | 8,3         | 6,5 – 8,5      |
| Sulfat        | mg/l    | 126         | 400            |
| Bikarbonat    | mg/l    | 552         |                |
| Chlorid       | mg/l    | 550         | 250            |
| Leitfähigkeit | mS/cm   | 2,6         | 0,25           |

**Tabelle 4.68: Qualität des Grundwassers für einen gemüseverarbeitenden Betrieb im Vergleich zu den WHO-Richtwerten**

#### Beispielanlagen

Eine gemüseverarbeitende Anlage in Belgien.

#### Referenzliteratur

[35, OECD, 2001]

4.5.7.3.4 Wiederverwendung des Gemüsewaschwassers nach Behandlung – Fallstudie]

Beschreibung

Ein Systemanbieter entwickelte, baute und übergab eine schlüsselfertige Kläranlage, die in einem gemüseverarbeitenden Betrieb in Großbritannien eine Wiederverwendung von bis zu 55 % des Abwassers erlaubt. Die Kläranlage beinhaltet eine Vorbehandlung und belüftete Misch- und Ausgleichsbecken, gefolgt von einem modernen Membranbioreaktor (MBR), Umkehrosmose und UV-Desinfektion. Zur wirkungsvollen Trennung der Biomasse wird eine Ultrafiltration eingesetzt, das Kreislaufsystem wird aus den zwei Bioreaktorbecken gespeist. Die Anlage läuft vollautomatisch mit SPS und Verfolgung der wichtigsten Prozessparameter wie Strömungen, Gehalt an gelöstem Sauerstoff, pH-Wert und Temperatur. Ein integriertes Belüftungs- und Rührsystem trägt die notwendigen hohen Sauerstoffmengen in die konzentrierte Biomasse ein.

Abbildung 4.43 zeigt ein Diagramm einer Kläranlage in einem gemüseverarbeitenden Betrieb.

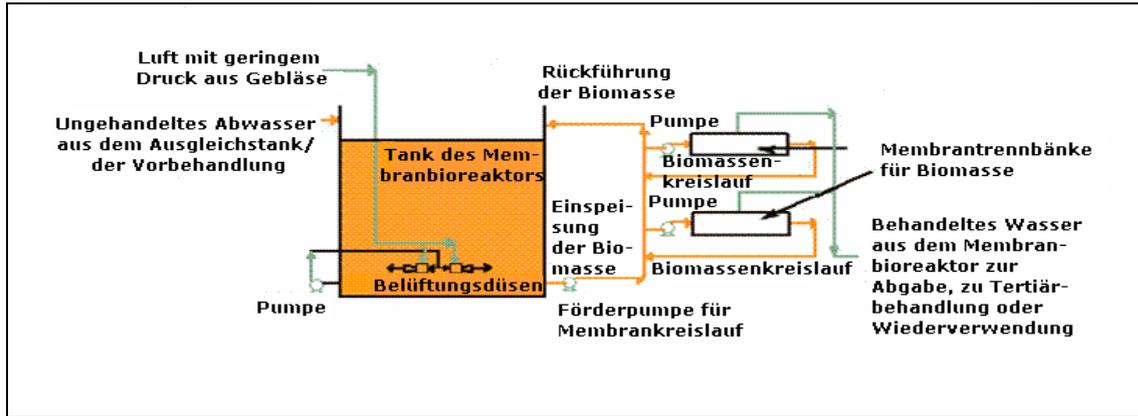


Abbildung 4.43: Kläranlage mit Wiederverwendung des Wassers in einem gemüseverarbeitenden Betrieb [102, UK, 2002]

Erreichbare Umweltvorteile

Geringerer Wasserverbrauch, da das Wasser wiederverwendet wird. Geringere Verschmutzung des Abwassers.

Betriebsdaten

Beim Waschen von Gemüse entstehen in der Anlage insgesamt bis zu 1.200 m<sup>3</sup> Abwasser pro Tag; davon werden bis zu 815 m<sup>3</sup> pro Tag in den Hochleistungs-Membranbioreaktor gepumpt. Nach der Umkehrosmose und der UV-Desinfektion können bis zu 650 m<sup>3</sup>/Tag wieder zum Waschen von Salat und als Prozesswasser in den Betrieb zurückgepumpt werden. Der Gesamt-CSB des in den Ausgleichstank eingeleiteten Wassers beträgt bis zu 1.440 kg/Tag, je nach Produktionsmenge.

Die intensiven aeroben Bedingungen in den Bioreaktoren, von denen jeder für einen Gehalt von 15.000 mg/l suspendierter Feststoffe in einem Flüssigkeitsgemisch (MLSS) ausgelegt ist, in Kombination mit dem relativ hohen Schlammalter bedeuten, dass eine hohe Endqualität des Abwassers mit viel geringerem Platzbedarf erzielt werden kann. Das Volumen des Bioreaktors beträgt nur 20 % der Größe einer normalen Behandlungsanlage.

Nach vollständiger Behandlung erreicht etwa die Hälfte des Abwassers Trinkwasserqualität und kann innerhalb der Anlage wiederverwendet werden. Der ursprüngliche CSB von etwa 1.500 mg/l wurde auf nahezu Null gesenkt. Das Ultrafiltrationssystem zur Trennung der Biomasse liefert ein Permeat, das direkt in die Nachbehandlungsstufe der Umkehrosmose/UV-Desinfektion eingespeist werden kann.

Beispielanlagen

Eine gemüseverarbeitende Anlage in Großbritannien.

Referenzliteratur

[102, UK, 2002]

#### 4.5.7.3.5 Wiederverwendung des Wassers bei der Verarbeitung von Erbsen nach der Chlorierung

Eine mikrobielle Kontamination kann durch den Einsatz von Chlordioxid verhindert werden. Diese Substanz ist in einer für Trinkwasser zugelassenen Menge von 0,5 ppm wirksam gegen Biofilm. Abbildung 4.44 zeigt ein Diagramm einer vierstufigen Wasseraufbereitung in einer Konservenfabrik für Erbsen. In einige Ländern ist die Chlorierung von Wasser zum Waschen von angeliefertem Obst oder Gemüse nicht erlaubt. Die Wiederverwendung von Wasser in Verfahren, in denen das Wasser direkt mit dem Produkt in Berührung kommen kann, ist auch nicht immer erlaubt.



Abbildung 4.44: Wiederverwendung von Wasser in der Konservenindustrie [13, Environment Agency of England and Wales, 2000]

#### 4.5.7.3.6 Kartoffelverarbeitung

Obwohl die organischen Inhaltsstoffe des Abwassers aus der Kartoffelverarbeitung gut biologisch abbaubar sind, können bei der Behandlung des Abwassers Probleme auftreten, überwiegend aus folgenden Gründen [65, Germany, 2002]:

- die Abwasserbelastung mit Schadstoffen kann im Laufe des Tages, der Woche, des Jahres erheblich schwanken
- hohe Mengen an Verunreinigungen
- unausgewogene Zusammensetzung des Abwassers, z. B. überwiegend Kohlenhydrate, und manchmal unausgewogene Mineralstoffmengen
- Anwesenheit schaumbildender Substanzen, z. B. Proteine
- Gefahr der Bildung von Blähschlamm
- die Temperatur des Abwassers übersteigt manchmal 35 – 40 °C, wodurch der Einsatz von Verdampfungskühlern notwendig werden kann
- da es leicht zu anaeroben Fermentationsprozessen kommt, können unerwünschte Gerüche entstehen
- die während der Fermentation entstehenden Säuren können den pH-Wert auf 4 – 4,5 reduzieren. Diese Säuerung findet innerhalb von rund 2 Stunden statt.

In anaeroben/aeroben Behandlungssystemen ist es mit Blick auf die Gesamt-Stickstoffbelastung notwendig zu untersuchen, ob das gesamte Abwasser aus der Produktion behandelt werden kann oder nur Teilmengen, damit sichergestellt ist, dass in der aeroben Stufe noch genug Kohlenstoff zur Eliminierung des Stickstoffs vorhanden ist. Wenn die oben genannten Überlegungen berücksichtigt werden, ist es möglich, das hochkonzentrierte Abwasser aus der Kartoffelverarbeitung mit biologischen Verfahren zu reinigen. UASB-Reaktoren können für Kartoffelschälverfahren ungeeignet sein.

### 4.5.7.4 Pflanzliche Öle und Fette

#### 4.5.7.4.1 Abwasserbehandlung

In den vergangenen Jahren hat es umfangreiche Untersuchungen zur biologischen Behandlung von Abwasser aus der Gewinnung und Raffination von Speiseölen gegeben, die das Ziel hatten, die bislang unvermeidbaren Abwasserfrachten zu eliminieren. Beispielsweise können bei der Herstellung raffinierten Rapsöls etwa 10 – 12 m<sup>3</sup> Abwasser pro Tonne Rohstoff anfallen. Das Abwasser hat einen CSB von bis zu 5000 mg/l und enthält pro Liter bis zu 4500 mg an suspendierten Feststoffen und 1200 mg an lipophilen Stoffen [134, AWARENET, 2002]. Phosphor liegt in anorganischer und organischer Form vor. Die Untersuchungen fanden im Labor und im Pilotmaßstab statt. Die entwickelten Behandlungsstrategien wurde im Ergebnis in zwei Prototypsysteme im industriellen Maßstab implementiert. Beide Systeme sind auf die besonderen Betriebsbedingungen der Anlagen und die Situation vor Ort zugeschnitten. Die Prototypen werden weiterhin optimiert.

Zu den Primärbehandlungen im Sektor der pflanzlichen Öle gehören:

- Ausgleichsverfahren für Durchfluss und Befrachtung (siehe Abschnitt 4.5.2.3)
- Sedimentation (siehe Abschnitt 4.5.2.5)
- Fettabcheidung (siehe Abschnitt 4.5.2.2)
- Entspannungsflotation (siehe Abschnitt 4.5.2.6)
- Fällung (siehe Abschnitt 4.5.2.9) zur Reduzierung des Phosphorgehalts

Außerdem werden weitergehende Abwasserbehandlungsverfahren und aerobe Verfahren eingesetzt (siehe Abschnitt 4.5.3.1). Im Allgemeinen eignet sich das Abwasser gut für eine biologische Behandlung. Es können Belebtschlammverfahren (siehe Abschnitt 4.5.3.1.1), Tropfkörper (siehe Abschnitt 4.5.3.1.5) und Rotations-tauchkörper (siehe Abschnitt 4.5.3.1.7) eingesetzt werden. Sektorspezifische Faktoren, die die biologische Behandlung des Abwassers beeinflussen können, sind die Anwesenheit von schwerflüchtigen lipophilen Substanzen, Sulfat, höheren Phosphatidkonzentrationen und ein niedriger pH-Wert.

#### 4.5.7.4.2 Olivenöl

Siehe auch Abschnitt 4.7.4.1 zu Informationen über die Reduzierung der Abwassermenge und der Schadstoffbefrachtung während des Prozesses.

Das Abwasser aus Olivenmühlen stellt eines der am meisten belasteten Abwässer in der Nahrungsmittelproduktion dar und verursacht große Probleme in den Regionen Europas, in denen Olivenbäume kultiviert werden. Es hat einen sehr hohen CSB von 200.000 mg/l, einen niedrigen pH-Wert von 3 – 5,9 und einen hohen Feststoffanteil (TSS) von 20.000 mg/l. Zusätzlich erschwert der hohe Anteil an Polyphenolen im Abwasser aus der Olivenölherstellung mit Werten von bis zu 80.000 mg/l den Abbau durch Bakterien und gibt dem Wasser phytotoxische Eigenschaften.

Kleine Olivenmühlen, von denen viele unterhalb des Schwellenwerts der IVU-Richtlinie liegen, haben üblicherweise Verdunstungsteiche (siehe Abschnitt 4.5.3.1.4). Da das Abwasser über Monate in den offenen Teichen verdunsten kann, entwickeln sich Faulgerüche, und in vielen Fällen wird das Grundwasser durch Lecks verunreinigt. Die festen Reste werden dann zur Ausbringung auf landwirtschaftlichen Nutzflächen weitergegeben (siehe Abschnitt 4.1.6). Die direkte Lagerung in den Olivenhainen kann zur Kontamination des Grundwassers führen. Eine Anbindung an eine kommunale Kläranlage ist in der Regel nicht möglich, da sich die Olivenmühlen normalerweise in ländlichen Gegenden befinden, in denen es entweder keine kommunalen Kläranlagen gibt oder diese, falls vorhanden, nicht zur Behandlung von solchem Abwasser ausgelegt sind. Zur Behandlung von Abwasser aus der Olivenölproduktion kann auch eine thermische Konzentrierung (in diesem Dokument nicht beschrieben) eingesetzt werden.

Abwasser aus der Olivenölproduktion kann auch in einer anaeroben Kläranlage behandelt werden, wobei der CSB um 65 – 95 % reduziert wird. Die Investitionskosten dafür sind jedoch hoch, insbesondere weil die Olivenölmühlen nur saisonweise arbeiten. Erntezeit ist insgesamt von Oktober bis März; sie dauert aber pro Ort nur drei Monate. Die saisonale Arbeitsweise dieser Mühlen beeinträchtigt nicht die Behandlung, denn ein anaerober Faulbehälter kann nach dem Ruhezustand schnell wieder in Betrieb gesetzt werden, auch wenn es einige Zeit erfordert, bis die Behandlungsbedingungen wiederhergestellt sind.

Der hohe Polyphenolgehalt des Abwassers hemmt das Wachstum aerober Bakterien. Zudem führt die Autooxidation der phenolischen Verbindungen im Abwasser aus der Olivenölproduktion beim Kontakt mit der Luft zur Bildung makromolekularer Polyphenole, die noch schwieriger abzubauen sind.

Zu den alternativen Behandlungen des Abwassers von Olivenmühlen kann eine wirkungsvolle Primärbehandlung zur Entfernung der Feststoffe gehören (siehe Abschnitt 4.5.2). Durch Fällung (siehe Abschnitt 4.5.2.9) mit Hilfe eines optimalen Flockungsmittels wird ein großer Teil der gelösten und partikulären organischen Bestandteile beseitigt, deren Reste dann durch Filtration entfernt werden können (siehe Abschnitt 4.5.4.5). Die letzte Stufe ist dann der Einsatz der Membrantrennung (siehe Abschnitt 4.5.4.6), sodass die organische Befrachtung um insgesamt 95 % verringert wird. Dies wird zwar derzeit noch untersucht, könnte aber für die Zukunft eine Lösung sein.

Tabelle 4.69 zeigt einen Vergleich alternativer Behandlungsverfahren für Abwasser aus der Olivenölherstellung.

| Verfahren                  | Vorteile   | Nachteile  |
|----------------------------|--|--|
| Ausbringen auf Nutzflächen | Steigerung der Fruchtbarkeit wegen des Gehalts an Kalium, Magnesium und organischer Bestandteile | Verunreinigung des Grundwassers<br>hoher Salzgehalt<br>gesetzliche Einschränkungen<br>negative Auswirkungen auf die Vegetation, falls bestimmte Polypyhenolmengen überschritten werden |
| Verdunstungs-<br>teich     | Geringe Kosten<br>keine spezialisierten Mitarbeiter erforderlich                                 | Große Flächen erforderlich<br>Faulgeruch und Insekten<br>Verunreinigung des Grundwassers, wenn der Teich nicht richtig abgedichtet ist   |
| Thermische Konzentrierung  | Schnelleres System   | Hoher Stromverbrauch und hohe Kosten<br>Krustenbildung in den Verdampfern  |
| Anaerobe Verfahren         | Geringer Energieverbrauch<br>Methanentwicklung<br>stabilisierter Schlamm                         | Teure Installation   |

**Tabelle 4.69:** Vergleich alternativer Behandlungsverfahren für Abwasser aus der Olivenölherstellung [134, AWARENET, 2002]

#### 4.5.7.4.3 Mehrstufige Abwasserbehandlung bei der Raffination pflanzlicher Öle – Fallstudie

##### Beschreibung

Die Behandlung, die aus einer Kombination von Techniken besteht, wird in einer als Beispielanlage dienenden Speiseölraffinerie, in der besondere Bedingungen herrschen, angewandt. Der Einsatz dieser Behandlung in anderen Anlagen sollte vorher getestet werden, z. B. in einer Pilotanlage.

Die Technik wird für die Behandlung des Abwassers aus der Raffination von Rohölen und Fetten in der Anlage eingesetzt. Die Abwässer der getrennten Teilströme aus der Seifenspaltung (Sauerwasser), der Lagerung und Reinigung werden zusammengeführt.

Das System besteht aus den folgenden Stufen:

- Trennung (siehe Abschnitt 4.1.7.8)
- Fettabscheidung (siehe Abschnitt 4.5.2.2) in getrennten Strömen
- Misch- und Ausgleichsverfahren für Durchfluss und Befrachtung (siehe Abschnitt 4.5.2.3)
- Entspannungsflotation (siehe Abschnitte 4.5.2.6) bei niedrigem pH-Wert und ohne Fällung zur Entfernung freier lipophiler Stoffe
- Neutralisation (siehe Abschnitt 4.5.2.4) und Koagulation zur Entfernung der emulgierten Öle/Fette
- Entspannungsflotation (siehe Abschnitte 4.5.2.6) mit Fällung der koagulierten Öle/Fette
- Belebtschlammverfahren (siehe Abschnitt 4.5.3.1.1) in kaskadierenden Stufen zur Behandlung unter den Bedingungen mit Pfropfenströmung

- Entspannungsflotation (siehe Abschnitt 4.5.2.6) zur Entfernung von Überschuss-Schlamm
- Im Klarwasserbecken: Sedimentation (siehe Abschnitt 4.5.2.5) der restlichen suspendierten Feststoffe und zum Ausgleich von Abfluss und Belastung (siehe Abschnitt 4.5.2.3)

### Erreichbare Umweltvorteile

Verringerung des CSB im Abwasser um über 95 %. Auch Verringerung des Phosphorgehalts.

### Medienübergreifende Auswirkungen

Verwendung höherer Mengen chemischer Substanzen wie Natronlauge und Koagulationsmittel zur Eliminierung der Fette. Höherer Energieverbrauch für die physikalischen und biologischen Verfahrensschritte. Es fällt Schlamm an.

### Betriebsdaten

In Tabelle 4.70 sind die Eigenschaften des Abwassers vor und nach der Behandlung aufgeführt. Der Phosphoranteil wird um etwa 50 % allein durch die biologische Absorption mittels Assimilation in der Biomasse des Schlamms reduziert. In Abwässern, die Phosphatide, also organische P-Verbindungen, enthalten, kann keine Fällung vorgenommen werden.

| Parameter   | Einheit           | Eintritt | Austritt |
|---|-------------------|----------|----------|
| Abwassermenge   | m <sup>3</sup> /h | <25      |          |
| CSB   | mg/l              | 2.500    | <150     |
| BSB <sub>5</sub>  | mg/l              |          | <5       |
| Lipophile Stoffe  | mg/l              | **100    | –        |
| Phosphor* (P <sub>gesamt</sub> )                                      | mg/l              | <140     | <70      |
| Sulfat bis zu   | mg/l              | 12.000   | –        |
| * Herkunft des Phosphors: Phospholipide als Phosphatide und Lecithine |                   |          |          |
| **Bestimmt nach der nunmehr ungültigen Methode (DIN 38509, H 17)      |                   |          |          |

**Tabelle 4.70:** Eigenschaften des Abwassers vor und nach der Behandlung.

Tabelle 4.71 zeigt die Werte für den Energieverbrauch.

| Energiequelle      | Verbrauch                        |
|--------------------|----------------------------------|
| Dampf              | 12,5 kWh/t nicht raffiniertes Öl |
|                    | 45 MJ/t nicht raffiniertes Öl    |
|                    | 16 kg/t nicht raffiniertes Öl    |
| Elektrischer Strom | 11,5 MJ/t nicht raffiniertes Öl  |
|                    | 3,2 kWh/t nicht raffiniertes Öl  |

**Tabelle 4.71:** Energieverbrauchswerte

Tabelle 4.72 zeigt die Betriebsparameter eines Systems zur Abwasserbehandlung in einer Anlage der Öl- und Fettverarbeitung

|  |                            |
|--|----------------------------|
| <b>Stufe 1: Abkühlung, Neutralisation (NaOH), Zugabe von Koagulierungsmitteln und Harnstoff</b>  |                            |
| Entspannungsflotation bei niedrigem pH-Wert  | Fläche = 25 m <sup>2</sup> |
| Entspannungsflotation bei neutralem pH-Wert  | Fläche = 25 m <sup>2</sup> |
| <b>Stufen 2 – 3: Kaskadierendes Belebtschlammssystem (Belüftung + Entspannungsflotationsbecken)</b>  |                            |
| Reaktor 1: Volumen 630 m <sup>3</sup>  |                            |
| Reaktor 2: Volumen 1270 m <sup>3</sup>   |                            |
| Verweilzeit ca. 35 Stunden   |                            |
| Entspannungsflotation Oberfläche   | Fläche = 45 m <sup>2</sup> |
| <b>Stufe 4: Klarwassertank, Lagertank für gereinigtes Abwasser zur Sedimentation der restlichen suspendierten Feststoffe, Puffer für Spülzwecke, Ablaufpumpstation</b>   |                            |
| Volumen des Klarwassertanks 279 m <sup>3</sup>   |                            |
| <b>Stufe 5: Schlammbehandlung</b>  |                            |
| Schlammagerbecken mit feinblasiger Belüftung zur aeroben Stabilisierung des Überschuss-Schlamm. Schlammagerbecken für fetthaltigen Schlamm aus der chemischen/ physikalischen Primärbehandlung mit grobblasiger Belüftung zur aeroben Stabilisierung des Schlamm |                            |

**Tabelle 4.72: Beschreibung eines Systems zur Abwasserbehandlung in einer Anlage der Öl- und Fettverarbeitung**

#### Anwendbarkeit

Ölraffinerien, bei denen keine bessere Phosphorentfernung erforderlich ist. Tabelle 4.73 zeigt eine Zusammenfassung der Anwendungsparameter.

|                                     |  |
|-------------------------------------|--|
| <b>Einschränkungen</b>              | Geringe organische Schlammbelastung  |
|                                     | Gute Fetttrennung im Primärverfahren   |
|                                     | Keine Vorfällung der Phospholipide möglich   |
|                                     | Gleichzeitige Fällung bei hohen Phosphorgehalten schädlich für Biozönose   |
|                                     | Nachfällung zur Sicherstellung der Einhaltung der P-Werte nur mit erheblicher Überdosierung möglich                |
| <b>Zuverlässigkeit des Betriebs</b> | Eingeschränkt, da erhebliche, nicht vermeidbare Schwankungen in der Qualität des unbehandelten Abwassers auftreten |
|                                     | System erfordert sehr viel Aufmerksamkeit vom Bediener   |

**Tabelle 4.73: Zusammenfassung der Anwendungsparameter**

#### Wirtschaftliche Aspekte

Für die Entwicklung und den Bau dieses Systems sind erhebliche Investitionen notwendig. Es entstehen Kosten aufgrund des höheren Energieverbrauchs, für Wartung und Reparaturen, für das Bedienpersonal und eine höhere Abfallmenge. In der Beispielanlage wurde die Technik mit Hilfe externer finanzieller Unterstützung implementiert.

#### Anlässe für die Umsetzung

Strengere behördliche Anforderungen an Abwasseranfall und -qualität. Lokale Bedingungen des Gewässers, in die eingeleitet wird. Zum Zeitpunkt der Entscheidung gebremste Verfügbarkeit anderer Alternativen. Demonstrationssystem gefördert mit öffentlichen Mitteln.

#### Beispielanlagen

Eine Raffinerie für pflanzliche Öle und Fette in Deutschland.

#### Referenzliteratur

[65, Germany, 2002, 182, Germany, 2003, 185, CIAA-FEDIOL, 2004]

### **4.5.7.5 Molkereiprodukte**

#### **4.5.7.5.1 Eigenschaften des Abwassers**

Eigenschaften des Abwassers aus Molkereien, die für die Behandlung wichtig sind [13, Environment Agency of England and Wales, 2000, 65, Germany, 2002]:

- große tägliche Schwankungen des Volumenstroms
- schwankender pH-Wert
- Abwasser kann einen Stickstoffmangel aufweisen, sofern das Rohwasser nicht einen hohen Nitratgehalt hat oder Salpetersäure verwendet wird
- Abwasser kann hohe Phosphorgehalte aufweisen, wenn Phosphorsäure zur Reinigung verwendet wird Milch hat ebenfalls einen hohen Phosphorgehalt, z. B. 93 mg P/100 g Vollmilch
- die Behandlung von Molkereiabwasser führt zu einer geringeren Überschussschlammmenge als die Behandlung von Haushaltsabwasser, was z. B. auf den geringeren Anteil suspendierter Feststoffe, die geringere spezifische Schlammbelastung und die höheren Abwassertemperaturen zurückzuführen ist
- trotz der Nutzung vorgeschalteter Ausgleichsbecken empfiehlt sich die Berücksichtigung von Spitzenfrachten bei der Planung der Sauerstoffversorgung.

### 4.5.7.5.2 Abwasserbehandlung

Im Molkereisektor werden Feststoffe aus dem Waschwasser von Fahrzeugwaschanlagen im Allgemeinen bereits an der Quelle entfernt. Dazu werden Sand- oder Kiesabscheider eingesetzt, oder das Regenwasser der versiegelten Oberflächen wird generell in das Abwasserbehandlungssystem der Anlage eingeleitet. Anschließend wird das Abwasser im Allgemeinen aufgeteilt (siehe Abschnitt 4.1.7.8), und zwar nach hohem Feststoffgehalt, sehr hohem BSB und sehr hoher Salinität. Nach der Aufteilung erfolgt die Primärbehandlung, für die folgende Techniken verwendet werden können:

- Sieben/Rechen (siehe Abschnitt 4.5.2.1)
- Ausgleichsverfahren für Durchfluss und Befrachtung (siehe Abschnitt 4.5.2.3)
- Neutralisation (siehe Abschnitt 4.5.2.4)
- Sedimentation (siehe Abschnitt 4.5.2.5)
- Entspannungsflotation (siehe Abschnitt 4.5.2.6)
- Zentrifugation (siehe Abschnitt 4.5.2.8)
- Fällung (siehe Abschnitt 4.5.2.9)

Nach der Primärbehandlung kann eine weitergehende Behandlung des Abwassers erforderlich sein. Für Abwasser mit einem BSB von mehr als 1.000 – 1.500 mg/l werden anaerobe Behandlungsverfahren eingesetzt (siehe Abschnitt 4.5.3.2). Anaerobe Techniken sind in Europa für Molkereiabwässer mit einem BSB von mehr als 3.000 mg/l weit verbreitet. Nach der Oberflächenbelüftung kann das entstehende Abwasser aus dem anaeroben Verfahren direkt in eine kommunale Kläranlage eingeleitet werden. Trotzdem kann das Risiko einer Phosphorfreisetzung im eingeleiteten Abwasser bestehen, wenn anaerobe Verfahren verwendet werden. Für geringer befrachtete Abwasserströme wird eine aerobe Behandlung (siehe Abschnitt 4.5.3.1) eingesetzt.

Abbildung 4.45 zeigt das Flussdiagramm einer für Molkereiabwässer üblichen Abwasserbehandlung.

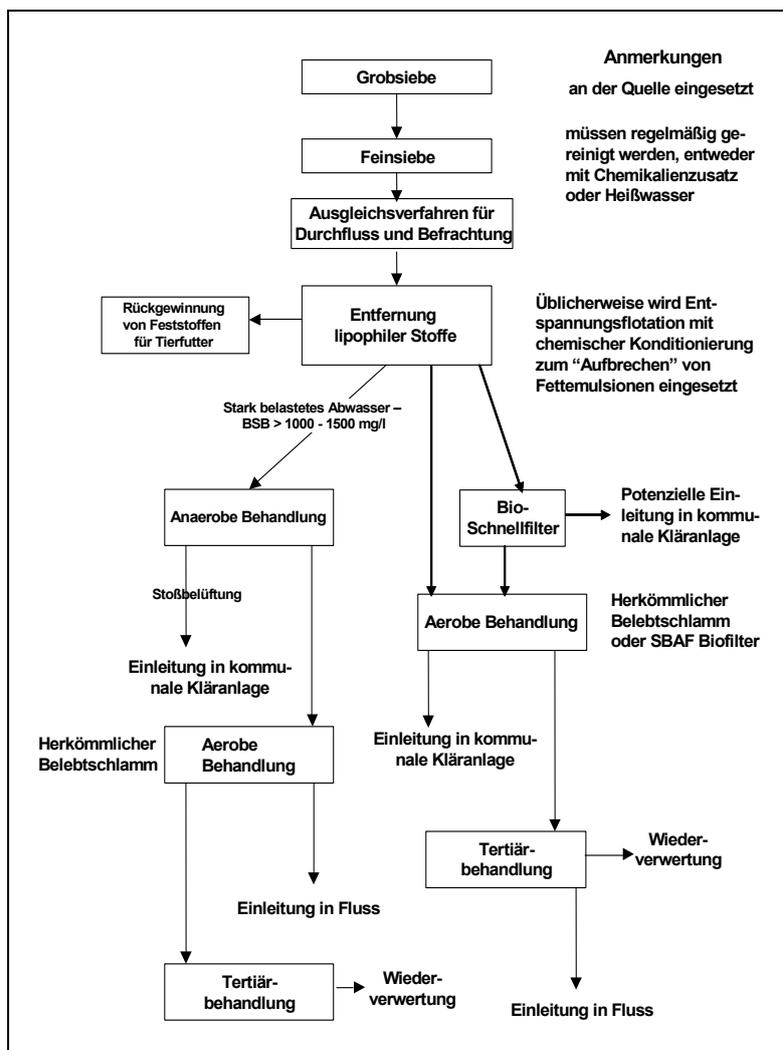


Abbildung 4.45: Übliche Abwasserbehandlung in Molkereien [13, Environment Agency of England and Wales, 2000]

## 4.5.7.6 Stärke

### 4.5.7.6.1 Eigenschaften des Abwassers

Abwasser aus dem Stärkesektor enthält in hohen Konzentrationen organische Substanzen, die leicht biologisch abbaubar sind. CSB und BSB ergeben sich durch die Hydrolyse und Fermentierung u. a. von reduzierten Zuckern, flüchtigen Säuren und Aldehyden. Der Gehalt an suspendierten Feststoffen ist nicht hoch.

Auch Stickstoff ist im Abwasser vorhanden. Er entsteht aus Verbindungen, die beim Abbau von Proteinen entstehen, z. B. Harnstoff und Ammoniak. Der Stickstoffgehalt scheint in Abwässern aus der Kartoffelverarbeitung höher zu sein als in Abwässern aus der Getreideverarbeitung. Metalle wie Zn, Ni und Cr finden sich in sehr begrenzten Mengen. Wenn sie vorliegen, stammen sie aus der Korrosion von Metallgefäßen und -leitungen sowie aus dem Rohmaterial, beispielsweise Mais, Reis und Kartoffeln.

### 4.5.7.6.2 Abwasserbehandlung

In der Primärbehandlung von Abwasser aus der Stärkeproduktion kommen folgende Techniken zum Einsatz:

- Ausgleichsverfahren für Durchfluss und Belastung (siehe Abschnitt 4.5.2.3)
- Sedimentation (siehe Abschnitt 4.5.2.5)
- Entspannungsflotation (siehe Abschnitt 4.5.2.6).

Wenn eine weitere Behandlung erforderlich ist, werden weitergehende Abwasserbehandlungstechniken eingesetzt. Anaerobe Verfahren (siehe Abschnitt 4.5.3.2) kommen zur Anwendung, wenn eine starke organische Befruchtung vorliegt und wenig suspendierte Feststoffe enthalten sind. Allerdings werden den Angaben zufolge manchmal auch lange anaerobe Behandlungen bei Abwässern mit hohen Gehalten an suspendierten Feststoffen eingesetzt. Es kommt dabei zu einer Methanisierungsreaktion, bei der Biogas entsteht, das 50 – 70 Volumenprozent Methan enthält und im Allgemeinen in einem Kessel rückgewonnen wird. Der Vorteil dieser Behandlung besteht darin, dass ohne Schlammproduktion und unter Energieeinsparung der CSB gesenkt wird. Die Optimierung einer solchen Reaktion ist jedoch schwierig, und die Effizienz kann zwischen 50 und 80 % des CSB schwanken. Ob eine anaerobe Behandlung durchgeführt wird oder nicht, hängt auch von den Frachtverhältnissen ab, z. B. CSB:N, BSB:N und N:P. Das CSB:N-Verhältnis sollte hoch genug sein, damit Bakterien sowohl in anaeroben als auch in aeroben Reaktoren wachsen können. Da jedoch die CSB- und BSB-Entfernungsraten niedrig sind, wird eine weitere Behandlung benötigt.

Der nächste Schritt ist im Allgemeinen eine aerobe Behandlung (siehe Abschnitt 4.5.3.1). Sauerstoff wird entweder durch Oberflächenbelüfter oder durch Einblasen von Luft am Beckenboden zugeführt. Wenn das Abwasser einen CSB von über 10.000 mg/l hat, sollte es nicht ausschließlich einer aeroben Behandlung unterzogen werden. Für weniger stark verschmutztes Abwasser wie das Brüdenkondensat aus Systemen zur Aufkonzentrierung oder Wasch- und Schwemmrinnenwasser aus der Kartoffelstärkeproduktion sind aerobe Techniken jedoch geeignet. Insbesondere bei der Behandlung von Brüdenkondensat ist es wichtig, für ein ausgewogenes Nährstoffverhältnis (N:P) zu sorgen. Außerdem ist damit zu rechnen, dass Abwasser aus der Stärkemodifizierung extrem unausgeglichene organische Frachten aus Kohlehydraten hat und es möglicherweise zu Problemen durch Blähschlamm Bildung kommt [65, Germany, 2002].

Schließlich umfasst die nachsorgende Behandlung des Abwassers auch die biologische Nitrifikation/Denitrifikation (siehe Abschnitt 4.5.4.1). Angaben zufolge ist eine nachsorgende Behandlung des Abwassers nicht immer erforderlich.

Die angegebene Zusammensetzung von Abwasser nach der Behandlung ist Tabelle 4.74 zu entnehmen.

| Parameter               | Konzentration (mg/l) |         |
|-------------------------|----------------------|---------|
|                         | Minimum              | Maximum |
| BSB <sub>5</sub>        | 5                    | 20      |
| CSB                     | 50                   | 300     |
| Suspendierte Feststoffe | 10                   | 60      |
| Gesamtstickstoff        | 2                    | 50      |
| Gesamtphosphor          | 1                    | 5       |

**Tabelle 4.74:** Eigenschaften von Abwasser aus dem Stärkesektor nach der Behandlung [115, CIAA-AAC-UFE, 2002]

Angaben zufolge wird Abwasser aus dem Stärkesektor manchmal nur einer vorläufigen Abwasserbehandlung wie der Sedimentation (siehe Abschnitt 4.5.2.5) unterzogen und dann zur Ausbringung auf Böden abgegeben (siehe Abschnitt 4.5.2.5).

#### 4.5.7.6.3 Wiederverwendung von Prozesswasser bei der Kartoffelstärkeherstellung

##### Beschreibung

Bei der Herstellung von Stärke und Stärkederivaten aus Kartoffeln können große Abwassermengen anfallen. In Abbildung 4.46 ist ein System für die Wiederverwendung von Kartoffelfruchtwasser und Prozesswasser zusammenfassend dargestellt.

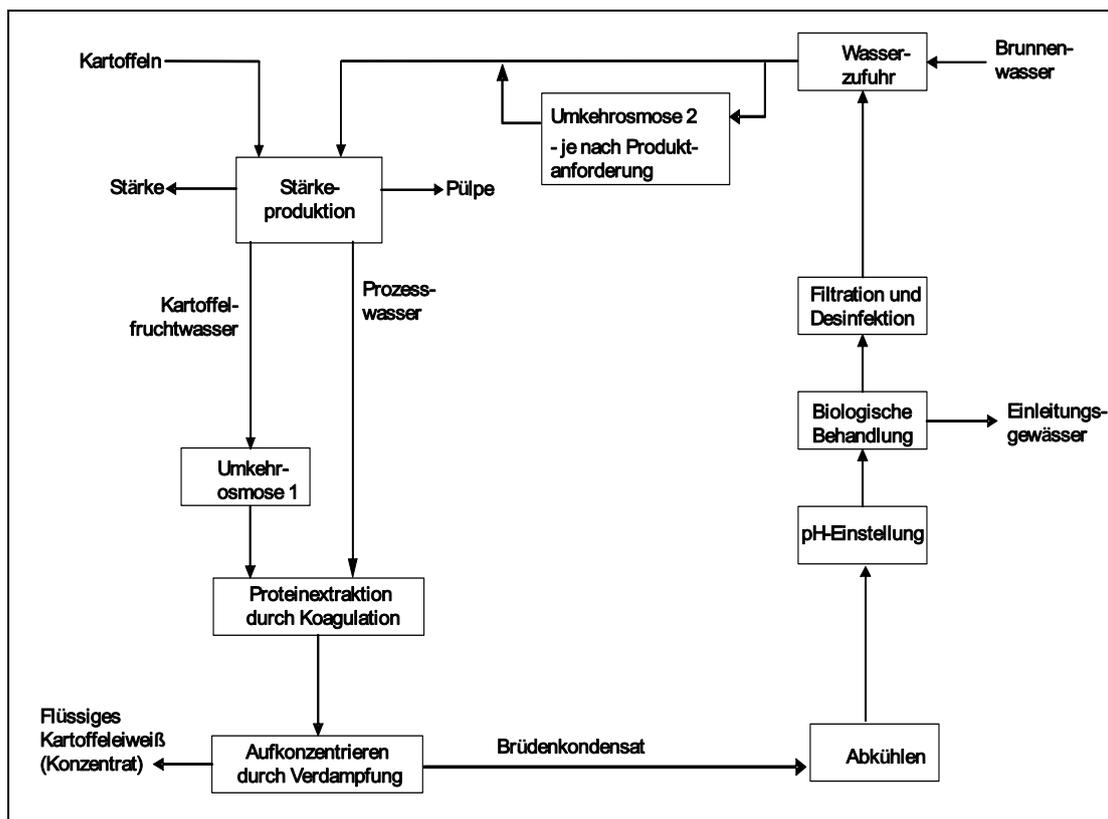


Abbildung 4.46: Wasserkreislauf in einer Kartoffelstärkeanlage

Zuerst wird das Kartoffelwasser durch Umkehrosmose behandelt. Das behandelte Kartoffelfruchtwasser wird dann zusammen mit dem Prozesswasser zur Proteinextraktion durch Koagulation weitergeleitet. Der nächste Prozessschritt ist die Aufkonzentrierung des entproteinierten Kartoffelfruchtwassers und des Prozesswassers durch Verdampfung. Das in diesem Verdampfungsschritt gewonnene Brüdenkondensat wird abgekühlt und sein pH-Wert eingestellt, bevor es in die biologische Kläranlage eingeleitet wird. Ein Teil des aufgereinigten Wassers wird einer weiteren Behandlung unterzogen, bei der es zuerst durch Sand gefiltert und dann desinfiziert wird. Das rückgewonnene Wasser wird mit frischem Wasser vermischt und in den Produktionsprozess zurückgeführt. Je nach den Produktanforderungen kann auch ein zweiter Umkehrosmoseschritt durchgeführt werden.

#### Erreichbare Umweltvorteile

Rückgang des Frischwasserverbrauchs und des Abwasservolumens.

#### Medienübergreifende Auswirkungen

Erhöhter Energieverbrauch und Überschussschlamm Bildung.

#### Betriebsdaten

In Tabelle 4.75 sind die Planungsvorgaben des Verdampfungsschritts für eine Beispielanlage angegeben. Die Merkmale der biologischen Abwasserbehandlung finden sich in Tabelle 4.76.

|                 |  |  |
|-----------------|--|--|
| <b>Zufuhr</b>   | Gesamtzufuhrstrom  | 213 m <sup>3</sup> /h (kontinuierliche Zufuhr)   |
|                 | Prozesswasser aus der Stärkeherstellung                  | Stromvolumen 1 = 110 – 145 m <sup>3</sup> /h<br>Trockensubstanzgehalt = 1,8 – 2 %<br>Temperatur<br>Zufuhr zur Proteinanlage = 38 – 40 °C<br>Nach der Proteinanlage = 86 °C |
|                 | Koaguliertes Kartoffelfruchtwasser aus der Proteinanlage | Stromvolumen 2 = 100 – 115 m <sup>3</sup> /h<br>Trockensubstanzgehalt = 5,5 – 6 %<br>Temperatur beim Austritt aus der Proteinanlage = 86 °C ± 1 %                          |
| <b>Abgabe</b>   | Produkt  | Flüssiges Kartoffeleiweiß mit mindestens 55 % Trockensubstanz  |
|                 | Kondensat  | so kalt und rein wie möglich   |
| <b>Leistung</b> | Dampfbereitstellung                                      | Mindestens 230 t/h   |
|                 | Vorverdampfer  | Mindestens 196 t/h   |
|                 | Endverdampfer  | Mindestens 34 t/h  |
|                 | Konzentrationstemperatur                                 | Maximal 87 °C  |
|                 | Reservekapazität   | Mindestens 15 % hinsichtlich der Dampfbereitstellungskapazität   |
|                 | Betriebszyklus   | Betriebsdauer mindestens 120 h<br>Reinigungsdauer maximal 9 h  |

Tabelle 4.75: Aufkonzentrierung von Kartoffelstärke-Prozesswasser durch Verdampfung – Planungsdaten

|  |  |   |
|--|--|---|
| <b>Abwasserart</b>   | Brüdenkondensat aus der Aufkonzentrierungsanlage     |   |
| <b>Verfahren</b>   | Belebtschlammverfahren<br>Sandfilter<br>Desinfektion |   |
| <b>Grundlegende Planungsdaten</b>  | Abwasservolumen                                      | 200 m <sup>3</sup> /h                         |
|  | CSB-Konzentration                                    | 1.500 ± 300 mg/l                              |
|  | CSB-Fracht   | 7.200 ± 1440 kg/d                             |
| <b>Abwassereigenschaften</b>   | CSB  | < 25 mg/l                                     |
|  | BSB <sub>5</sub>                                     | < 10 mg/l                                     |
| <b>Merkmale der Belebtschlammbehandlung</b><br>2 Becken, je 1.375 m <sup>3</sup> (= 2.750 m <sup>3</sup> ),<br>aerobes Volumen einschließlich vorgeschaltetem Selektor | Hydraulische Verweilzeit                             | = 13,8 h                                      |
|  | Hydraulische Fracht                                  | = 1,75 m <sup>3</sup> /m <sup>3</sup> pro Tag |
|  | CSB-Volumenfracht                                    | = 2,6 kg/m <sup>3</sup> pro Tag               |
|  | Schlammkonzentration                                 | = 5.000 g/m <sup>3</sup>                      |
|  | CSB-Schlammfracht                                    | = 0,52 kg CSB/kg                              |
|  | Trockensubstanz pro Tag                              |   |
|  | Rücklaufschlammvolumen                               | = maximal 200 m <sup>3</sup> /h               |
| <b>Nachklärung Sekundärklärung (Sedimentation)</b><br>1 rundes Querstrom-Absetzbecken  | Durchmesser  | = 23 m  |
|  | Wassertiefe  | = 5 m   |
|  | Volumen  | = 2076 m <sup>3</sup>                         |
|  | Oberfläche   | = 415 m <sup>2</sup>                          |
|  | Verweilzeit  | = 10,38 h                                     |
|  | Oberflächenfracht                                    | = 0,48 m/h                                    |
| <b>Sandfiltration</b><br>3 Anlagen   | Zufuhr Volumenstrom                                  | = (maximal) 3 x 70 m <sup>3</sup> /h          |
|  | Waschwasser Volumenstrom                             | = (maximal) 3 x 70 m <sup>3</sup> /h          |
|  | Hydraulische Fracht                                  | = 8 m/h                                       |
| <b>Desinfektion</b>  | UV-Desinfektion und ClO <sub>2</sub> -Zugabe         |   |

Tabelle 4.76: Merkmale der biologischen Abwasserbehandlung in einer Kartoffelstärkeanlage

Anwendbarkeit

Brüdenkondensat in der Kartoffelstärkeindustrie ist sehr weit abbaubar. Dadurch hängt die Behandlung durch Umkehrosmose- und Verdampfungsstufen von den jeweiligen Eigenschaften des Kartoffelfruchtwassers und des Prozesswassers ab.

Wirtschaftliche Aspekte

Durch den geringeren Verbrauch an Frischwasser werden Kosten gesenkt. Angaben zufolge ist das Abkühlen des behandelten Brüdenkondensats nicht notwendigerweise rentabel.

Anlässe für die Umsetzung

Angaben zufolge wurde Abwasser früher durch Ausbringung auf Nutzflächen entsorgt. Aber wegen des großen anfallenden Volumens, der hohen Transportkosten und des großen Oberflächenbedarfs konnte dieses Vorgehen nicht beibehalten werden. Das bei dieser Methode benötigte Speichervolumen ist im Vergleich zur Ausbringung auf Nutzflächen klein, da diese auf bestimmte Zeiträume des Jahres beschränkt ist. Im Gegensatz zur Ausbringung auf Nutzflächen ist diese Technik wetterunabhängig.

Beispielanlagen

Mindestens eine Anlage in Deutschland, in der Kartoffelstärke hergestellt wird.

Referenzliteratur

[65, Germany, 2002]

**4.5.7.7 Zucker****4.5.7.7.1 Abwasserbehandlung**

Angaben zufolge wird je nach Konfiguration der Kläranlage in Verarbeitungsanlagen für Zuckerrüben manchmal vor der Abwasserbehandlung eine Abwassertrennung (siehe Abschnitt 4.1.7.8) durchgeführt, um Abwasservermeidung durch Mehrfachnutzung zu erreichen. Es wird unterschieden zwischen dem Prozesswasser, also dem überschüssigen Kondensat aus der Konzentration (auch Fallwasser genannt), das einen hohen Ammoniakgehalt hat, dem Wasser aus der Kristallisation, dem Schwemmwasser (dekantiertes Rübentransportwasser) und dem Waschwasser (Reinigungswasser für die Rüben). Angaben zufolge wird das stark belastete dekantierte Rübentransportwasser getrennt gehalten. In manchen Anlagen wird das Kondensat (Fallwasser) zum Waschen der Rüben verwendet.

Beispiel 1

Die Erde aus dem Transportwasser wird in Absetzteichen (siehe Abschnitt 4.5.2.5) sedimentiert. Das dekantierte Wasser wird sowohl in anaeroben als auch in aeroben Abwasserteichen (siehe Abschnitt 4.5.3.1.4) behandelt. Die Benutzung von Abwasserteichen macht es möglich, das Wasser bei Trockenheit zur Landbewässerung zu nutzen, was auch den Entnahmebedarf von Wasser aus Oberflächengewässern oder aus dem Grundwasser senkt. In Südeuropa kann es zur Behandlung von Prozesswässern möglich sein, Abwasserteiche zur natürlichen Wasserverdunstung zu nutzen, da die Durchschnittstemperaturen hoch sind.

Eine weitere Behandlung ist erforderlich, wenn das Risiko von Geruchsbelästigungen besteht, oder aus Umweltgründen. In einem solchen Fall kann die vorherige Behandlung durch eine Oberflächenbelüftung verstärkt werden, der möglicherweise eine aerobe Behandlung vorausgeht (siehe Abschnitt 4.5.3.1).

Beispiel 2

Wenn aus Umweltgründen weitere Behandlungsstufen erforderlich ist, können Sedimentation (siehe Abschnitt 4.5.2.5) und anaerobe Behandlung (siehe Abschnitt 4.5.3.2), gefolgt von Oxygenierung und/oder aerober Fermentation (siehe Abschnitt 4.5.3.1) mit einem Nachklärverfahren angewandt werden.

Das stark belastete überstehende Wasser, das aus den Absetzteichen weitergeleitet wird, eignet sich sehr gut für die Behandlung mit anaeroben Techniken. Außerdem können die Betaine aus der Zuckerrübe, die aus organischen Stickstoffverbindungen bestehen, nur anaerob abgebaut werden. Deshalb ist etwa die Hälfte der Zuckerfabriken in Deutschland derzeit mit anaeroben Systemen ausgestattet [65, Germany, 2002].

Die organischen Stoffe im dekantiertes Rübentransportwasser zerfallen in kürzerkettige organische Säuren. Früher wurden pH-Anpassungen mit Zusätzen wie Kalk in Neutralisationsverfahren vorgenommen (siehe Abschnitt 4.5.2.4). Diese „Ansäuerung“ des Abwasserstroms ist jedoch für die anaerobe Behandlung ideal. Die Säurebildung ist eine wesentliche Reaktion, die unter anaeroben Bedingungen stattfindet, und bei der die länger-kettigen organischen Substanzen in leichter behandelbare organische Säuren zerfallen. Manche anaeroben Anlagen benötigen sogar ein Ansäuerungsbecken, das dem anaeroben Reaktor zur Ingangsetzung der Säurebildungsstufe vorgeschaltet ist. Die pH-Korrektur des Schwemmrinnenwassers ist also nicht mehr erforderlich.

Die Biogaserzeugung erfolgt bei höheren Temperaturen, z. B. bei 37 °C, obwohl eine langsamere Fermentation auch bei 20 °C oder darunter stattfinden kann. Infolge von Veränderungen der Zusammensetzung der

organischen Bestandteile des Abwassers und auch seines hohen Kalziumgehaltes kann es zu Betriebsproblemen kommen.

Im Methanreaktor führt das Vorliegen von Calcium aus dem Karbonisierungsprozess im Abwasser zusammen mit dem im Reaktor gebildeten Kohlendioxid zur Ausfällung von Calciumkarbonat. Die Erfahrung zeigt, dass unabhängig von der Konzentration im ankommenden Abwasser und unabhängig vom verwendeten Verfahren der Calciumgehalt auf etwa 0,3 – 0,7 kg/m<sup>3</sup> gesenkt wird. Das bedeutet, dass jährliche Calciumkarbonatfrachten von 300 – 1.000 Tonnen im Reaktor verbleiben. Dadurch ergeben sich Mischprobleme innerhalb des Systems sowie zusätzliche Arbeit und Kosten, um die betreffenden Pumpen, Wärmetauscher und Leitungsrohre funktionsfähig zu halten [65, Germany, 2002].

Ein Teil des anaerob behandelten Abwassers kann als Schwemmrinnenwasser wiederverwendet werden. Außerdem kann das im anaeroben Prozess anfallende Methan durch Verbrennung zur Trocknung von Zuckerrübenschnitzeln, die als Tierfutter verwendet werden, genutzt werden. Zum Vorwärmen des in den anaeroben Reaktor eintretenden Abwassers kann Niedertemperaturwärme genutzt werden [13, Environment Agency of England and Wales, 2000].

Überschüssiges Kondensat aus der Zuckerverarbeitung gilt als hoch mit Ammoniak befrachtet, der CSB wird jedoch als gering angesehen. Das empfohlene Verfahren zur Senkung der Ammoniakkonzentration ist die Anwendung aerober Techniken, die so konfiguriert sind, dass sie die Nitrifikation des Ammoniaks ermöglichen (siehe Abschnitt 4.5.4.1). Damit dieser Prozess stattfindet, muss dem Abwasserstrom Kohlenstoff aus einer externen Quelle zugeführt werden. Bei Anlagen, die anaerobe Techniken zur Behandlung des Schwemmwassers verwenden, reicht die Zusammenführung von Abwasser aus dem anaeroben Verfahren mit dem überschüssigen Prozesswasser meist aus, um eine ausgewogene Einspeisung für die aerobe Behandlungsstufe zu erzielen.

Manche Fabriken verwenden Hydrozyklone, um kalkbelasteten Bakterienschlamm aus dem System zu entfernen. In fast allen Fabriken ist es erforderlich, außerhalb der Saison den in den Reaktoren gebildeten Kalk mechanisch zu beseitigen, was in regelmäßigen Abständen alle 2 bis 5 Jahre erfolgt. Die Kalkkonzentrationen bei der Entfernung betragen etwa 800 – 1.000 kg/m<sup>3</sup> Trägermaterial. Da solche Betriebe saisonal arbeiten, muss das aerobe System, das dem anaeroben nachgeschaltet ist, entsprechend zum Saisonstart aktiviert werden. Bei Verwendung von Wirbelschichtbetten (siehe Abschnitt 4.5.3.2.7) ist das nicht unbedingt erforderlich. Kalk wird fast vollständig auf dem Trägermaterial ausgefällt, welches dann während des Betriebs abgezogen werden kann.

Nach diesem Schritt ist die Qualität des Abwassers möglicherweise ausreichend zur Einleitung in Oberflächengewässer. Alternativ dazu könnte die Abgabe an eine Kläranlage erfolgen. Zur potenziellen Wiederverwertung des einzuleitenden Abwassers kann ein Teil des Abwassers mit tertiären Techniken (siehe Abschnitt 4.5.4) behandelt werden.

### Beispiel 3

In Fällen, in denen Stickstoff und Stickstoffverbindungen begrenzt werden müssen, ist die Installation entsprechend geplanter Nitrifikations- und Denitrifikationssysteme erforderlich. Dafür stehen verschiedene biologische und nicht-biologische Techniken zur Verfügung, z. B. die Ammoniakstrippung (siehe Abschnitt 4.5.4.2) und die biologische Nitrifikation/Denitrifikation (siehe Abschnitt 4.5.4.2).

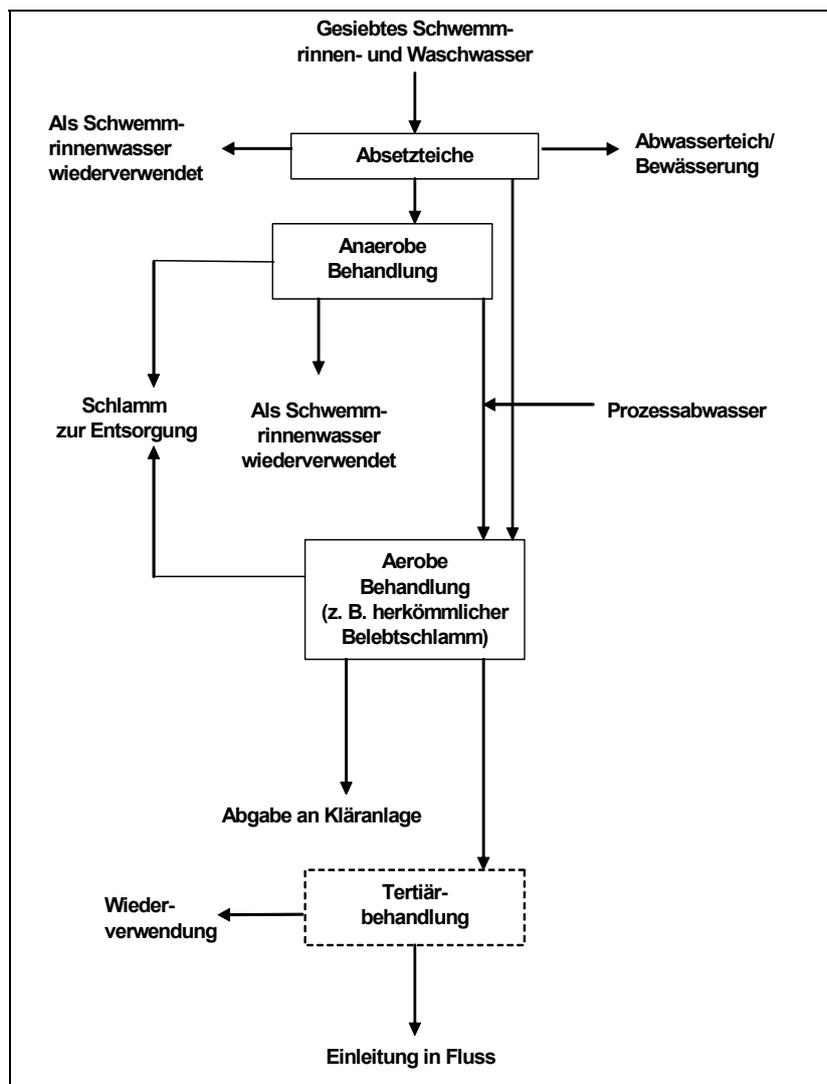
### Beispiel 4

Zuerst wird ein anaerobes Verfahren angewandt und das entstehende Biogas als Brennstoff genutzt. Später werden Stickstoff und Phosphor in einem aeroben Verfahren abgebaut.

Nach der Abwasserbehandlung wird das Wasser entweder in der Fabrik wiederverwendet oder in Oberflächengewässer eingeleitet.

### Beispiel 5

Abbildung 4.47 zeigt ein übliches Prozessflussdiagramm der Abwasserbehandlung in einer Zuckerrübenverarbeitungsanlage.



**Abbildung 4.47:** Übliche Möglichkeiten der Behandlung von Zuckerrübenabwasser [13, Environment Agency of England and Wales, 2000, 159, CIAA-CEFS, 2003]

Erzielte Emissionswerte

In Tabelle 4.77 ist die Leistung der Abwasserbehandlung in einer Anlage der Zuckerindustrie in Nordeuropa angegeben.

| Behandlung                            | BSB (mg/l) | Gesamtstickstoff (mg/l) | Gesamtphosphor (mg/l) |
|---------------------------------------|------------|-------------------------|-----------------------|
| Vor der Behandlung                    | 3.300      | 120                     | 10                    |
| Nach der anaeroben Behandlung         | 100        | 80                      | 8                     |
| Nach anaerober und aerober Behandlung | 2          | 10                      | 0,4                   |

**Tabelle 4.77:** Leistung der Abwasserbehandlung in einer Anlage der Zuckerindustrie in Nordeuropa [1, CIAA, 2002]

Die Angaben in Tabelle 4.78 betreffen Anlagen der dänischen Zuckerindustrie und gelten pro Tonne verarbeiteter Zuckerrüben.

| Parameter                                      | Gesamt Mittel (Bandbreite) | Keine Behandlung Mittel (Bandbreite) | Nach anaerober/aerober Behandlung |
|--|----------------------------|--------------------------------------|-----------------------------------|
| Abwasser m <sup>3</sup> /t verarbeiteter Rüben | 0,79<br>(0,53 – 1,10)      |                                      |                                   |
| Abwasser m <sup>3</sup> /t erzeugten Zuckers   | 5,13<br>(3,73 – 6,98)      | 5,59<br>(3,76 – 6,98)                |                                   |
| BSB <sub>5</sub> kg/t erzeugten Zuckers        | 10,3<br>(0,01 – 24,4)      | 14,6<br>(10,7 – 24,4)                | 0,01                              |
| Suspendierte Feststoffe kg/t erzeugten Zuckers | 1,25<br>(0,76 – 1,62)      | 1,16<br>(0,76 – 1,42)                | k. A.                             |
| Stickstoff kg/t erzeugten Zuckers              | 0,27<br>(0,01 – 0,56)      | 0,33<br>(0,19 – 0,56)                | 0,03                              |
| Phosphat kg/t erzeugten Zuckers                | 31,3<br>(0,81 – 83,2)      | 40,4<br>(27,5 – 83,2)                | 1,22                              |

**Tabelle 4.78: Abwassermengen und deren -eigenschaften in Anlagen der dänischen Zuckerindustrie [139, Nielsen E.H. Lehmann, 2002]**

Tabelle 4.79 zeigt spezifische Frachten von Abwasserverunreinigungen nach der biologischen Abwasserbehandlung.

| Parameter        | Produzierter Zucker (kg/t) |
|------------------|----------------------------|
| BSB <sub>5</sub> | 0,24                       |
| CSB              | 2,4                        |
| TOC              | 0,9                        |
| Gesamtstickstoff | 0,35                       |

**Tabelle 4.79: Abwasserfrachten nach der biologischen Behandlung während einer Zuckerrübensaison [152, Austria, 2002]**

Angaben zufolge wird das Abwasser aus Anlagen der Zuckerindustrie manchmal keiner Abwasserbehandlung unterzogen, sondern zur Ausbringung auf Böden abgegeben (siehe Abschnitt 4.1.6).

#### 4.5.7.8 Getränke

##### 4.5.7.8.1 Eigenschaften des Abwassers

Der Getränkesektor (alkoholische und alkoholfreie Getränke) ist sehr vielseitig. Das Abwasser lässt sich unterteilen in die Kategorien geringe Belastung/großes Volumen, hohe Belastung/ geringes Volumen, kontinuierliche regelmäßige Einleitungen und ernte-/saisonbedingte Einleitungen. Das Abwasser aus diesem Sektor ist in der Tendenz weitgehend biologisch abbaubar und enthält aktive Mikroorganismen.

##### 4.5.7.8.2 Abwasserbehandlung

Vor der Behandlung kann eine Abwassertrennung erfolgen (siehe Abschnitt 4.1.7.8). Dann können Ströme mit hohem Volumen und geringer Konzentration<sup>30</sup> möglicherweise entweder nach geeigneter Behandlung wiederverwertet oder ohne Behandlung direkt an die abgegeben oder vor der Abgabe mit behandeltem Abwasser

<sup>30</sup> Anm. d. UBA-Bearb.: Die Abwässer der Alkoholfreien Getränkeindustrie enthalten in Abhängigkeit von den hergestellten Getränken unterschiedliche Konzentrationen an Kohlenhydraten und Eiweißstoffen

vermischt werden. Welche Möglichkeiten zur Wahl stehen, hängt vom Einleitungsgewässer und den Einleitungsgenehmigungen ab [13, Environment Agency of England and Wales, 2000].

Im Allgemeinen können zur Behandlung von Abwasser aus dem Sektor „alkoholische und alkoholfreie Getränke“ die folgenden Primärbehandlungen erfolgen [13, Environment Agency of England and Wales, 2000]:

- Sieben/Rechen (siehe Abschnitt 4.5.2.1)
- Ausgleichsverfahren für Durchfluss und Abwasserfracht (siehe Abschnitt 4.5.2.3)
- Entspannungsflotation (siehe Abschnitt 4.5.2.6)
- Havariebecken (siehe Abschnitt 4.5.2.7)

Bei der Herstellung alkoholfreier Getränke werden biologische Behandlungssysteme erfolgreich eingesetzt.

Je nach Produktbereich und Verpackungssystem, also Einweg- oder Mehrwegverpackungen, kann die kontinuierliche oder zeitweilige Zugabe von Nährsalzen erforderlich sein. Reinigung und Desinfektion können zu vorübergehenden Spitzen in der Phosphorkonzentration führen, was dann für Direkteinleiter zu Problemen führen kann, selbst wenn ein Misch- und Ausgleichsbecken vorhanden ist, was den Angaben zufolge vor der biologischen Behandlung angeraten ist [65, Germany, 2002].

Für Abwasser mit einem BSB<sub>5</sub> von mehr als 1.000 – 1.500 mg/l werden anaerobe Behandlungsverfahren (siehe Abschnitt 4.5.3.2) mit anschließender Oberflächenbelüftung eingesetzt. Für geringer belastete Abwasserströme reicht eine aerobe Behandlung (siehe Abschnitt 4.5.3.1). Es kann ein zweistufiges biologisches System (siehe Abschnitt 4.5.3.3.2) verwendet werden, in dem auf eine anaerobe eine aerobe Behandlung folgt.

Für die Einleitung in Oberflächengewässer oder für eine Abwasserqualität, die die Wiederverwendung erlaubt, sind zusätzliche Behandlungsstufen erforderlich.

Wenn die Konzentrationen suspendierter Feststoffe im abgegebenen Wasser gering sein müssen, oder wenn das Abwasser wiederverwertet werden soll, ist eine nachsorgende Behandlung des Abwassers (siehe Abschnitt 4.5.4) notwendig. Desinfektion und Sterilisation (siehe Abschnitt 4.5.4.8) sind unabdingbar, wenn das Abwasser in Prozessbereichen als Wasser mit Trinkwasserqualität verwendet werden soll.

Manche Anlagen sind das ganze Jahr über in Betrieb, erzeugen aber saisonale Produkte. In solchen Anlagen entsteht das ganze Jahr hindurch eine allgemeine Grundbelastung aus Abwasser aus der laufenden Produktion. Während der entsprechenden Saison oder Erntezeit fällt in abwasserintensiven Prozessen zusätzliches Abwasser an. Die Art der Grundbelastung des Abwassers und der saisonal bedingten Abwasserbelastung beeinflussen die für die Anlage ausgewählten Abwasserbehandlungstechniken.

Üblicherweise ist das saisonale Abwasser stärker belastet als das Abwasser der Grundbelastung. Es gibt eine Reihe von Faktoren, die bei Auswahl der Techniken durch den Betreiber unter diesen Bedingungen eine Rolle spielen. Dazu gehört z. B. die Nähe von Einleitungspunkten für die innerbetrieblichen Abwasserströme und ob eine innerbetriebliche Zusammenlegung von Prozessströmen gegenüber einer getrennten Behandlung von Vorteil ist. Die Wirtschaftlichkeit der Errichtung einer Kläranlage, die während der Erntezeit in der Lage ist, erheblich höhere Frachten zu behandeln, muss geprüft werden.

Manches Abwasser benötigt nur bei getrennter Behandlung eine Vorbehandlung vor der Einleitung in eine Kläranlage. Das saisonale Abwasser ist üblicherweise stark belastet, fällt aber mit relativ geringem Volumen an und wird mit anaeroben Verfahren behandelt. Nach den anaeroben Verfahren kann das Abwasser üblicherweise nach einer Oberflächenbelüftung an eine kommunale Kläranlage abgegeben werden.

Wenn die innerbetrieblichen Abwasserströme gemeinsam behandelt werden sollen, muss die Kläranlage generell modular aufgebaut sein und zwei oder mehr parallel arbeitende Reaktoren haben, damit außerhalb der Saison ein Reaktor betrieben und während der Saison die anderen zur Erreichung der vollen Kapazität zugeschaltet werden können. Eine Technik, die dafür in Frage kommt, ist ein herkömmliches Belebtschlammverfahren (siehe Abschnitt 4.5.3.1.1), dem in der Zeit der hohen saisonalen Frachten Reinstsauerstoff (siehe Abschnitt 4.5.3.1.2) zugesetzt wird. Als Vorbereitung auf den erhöhten Durchfluss und die höhere Fracht kann eine zusätzliche Zufuhr für die Anlage nötig sein.

### 4.5.7.8.3 Brauwirtschaft

Normalerweise schwankt die anfallende Abwassermenge. Der Spitzendurchfluss kann das 2,5 – 3,5-fache des Durchschnittsdurchflusses betragen, je nachdem, wie dicht am Produktionsbereich die Messung erfolgt. Spitzendurchflusszeiten sind normalerweise kurz. Spitzendurchflüsse treten in der Brauerei und in der Bierproduktion im Zusammenhang mit Reinigungsaktivitäten auf. Im Verpackungsbereich kommt es zu Spitzendurchflüssen, wenn die Produktionslinie heruntergefahren wird und die Flaschenwaschmaschine und Tunnelpasteurisatoren geleert werden. Ein dritter Bereich, in dem es zu hohen Spitzen kommen kann, ist der Abwasserbehandlungsbereich während des Spülens von Filtern.

Die Konzentration der organischen Substanz hängt vom Verhältnis Abwasser zu Bier und von der Abgabe organischer Substanzen in die Kläranlage ab. Die übliche Abgabemenge organischer Substanz aus Brauereien bewegt sich normalerweise im Bereich von 0,8 bis 2,5 kg CSB/hl Bier. Es kann auch zu höheren Abgabemengen kommen, die sich auf die Einleitung von überschüssiger Hefe, Treber oder anderen konzentrierten Abfällen in die Kläranlage zurückführen lassen und die anders besser zu entsorgen wären. Die Herstellung von alkoholfreiem Bier kann zu sehr hohen Einleitungen führen, wenn der kondensierte Alkohol in die Kläranlage abgegeben wird.

Normalerweise hat das Prozessabwasser einen geringen Gehalt an nicht biologisch abbaubarer Bestandteile. Brauereiabwasser weist üblicherweise ein CSB/BSB-Verhältnis von 1,5 bis 1,7 auf, was darauf hindeutet, dass es leicht abbaubar ist.

Während der Primärbehandlung ist die Neutralisation (siehe Abschnitt 4.5.2.4) unabdingbar. Die Dosierungskapazität der Neutralisationsanlage hängt vom Betrieb der Brauerein, insbesondere von Planung und Betrieb der Abgabe der Laugenbäder aus Flaschenwäschern und CIP-Tanks ab. Andere Alternativen bestehen in der Verwendung von Rauchgas von der Kesselanlage oder überschüssigem CO<sub>2</sub> aus der Fermentation zur Neutralisation von Laugen in CIP-Anlagen oder des Überlaufs von Flaschenreinigungsanlagen. Das Gerät kann ein Wäscher oder ein einfacheres System sein, bei dem das Gas in eine Senkgrube abgelassen wird.

Die weitergehende Abwasserbehandlung kann aerobe (siehe Abschnitt 4.5.3.1) und/oder anaerobe (siehe Abschnitt 4.5.3.1) Verfahren umfassen. Die am häufigsten für die Behandlung von Brauereiabwasser benutzte aerobe Methode ist das Belebtschlammverfahren (siehe Abschnitt 4.5.3.1.1). Dessen ungeachtet hat die Verwendung eines anaeroben Verfahrens den Vorteil, dass weniger (oder keine) Nährstoffe für das nährstoffarme Brauereiabwasser benötigt werden. Die am häufigsten benutzten anaeroben Techniken sind UASB-Reaktoren (siehe Abschnitt 4.5.3.2.4) und EGSB-Reaktoren (siehe Abschnitt 4.5.3.2.8).

Der Überschussschlamm kann einen wesentlichen Teil der Festabfallzeugung der Brauerei ausmachen und muss entsorgt werden. Der Schlamm wird Berichten zufolge auch auf landwirtschaftlichen Nutzflächen ausgebracht (siehe Abschnitt 4.1.6).

Wenn die Abwasseranforderungen strenger sind als ein BSB<sub>5</sub> von 15 mg/l und eine Konzentration suspendierter Feststoffe von 20 – 30 mg/l, ist eine nachsorgende Behandlung des Abwassers erforderlich (siehe Abschnitt 4.5.4).

### 4.5.7.8.4 Wiederverwertung von Wasser in einer Brauerei

#### Beschreibung

Am Ende der Maischeabscheidung wird der Rückstand, eine stark verdünnte Würze, frei ablaufen gelassen, bis ein akzeptabler Feuchtigkeitsgehalt des Trebers erreicht ist. Nach dem Entfernen des Trebers werden die feinen Bestandteile, die sich unter dem Senkboden abgelagert haben, mit einer Heißwasserreinigung von unten entfernt, und die Öffnungen der Siebplatte werden durch eine Spülung mit Heißwasser von oben freigehalten. Die stark verdünnte Würze hat einen hohen Gehalt an suspendierten Feststoffen, Lipiden und Polyphenolen und gilt traditionell als ungeeignet für die Wiederverwendung im Prozess und wird daher an die Kläranlage abgegeben. Dadurch entsteht ein erheblicher Verlust von Wasser, Energie und Extrakt.

Das Abwasser aus dem Läuterbottich ist ein wesentlicher Bestandteil des Gesamtabwassers einer Brauerei. Die Belastung des Läuterbottichabwassers hängt von mehreren Faktoren ab. Hinsichtlich des Wasserhaushalts gilt, dass das Abwasservolumen umso größer ist, je geringer der Feuchtigkeitsgehalt des verbrauchten Trebers ist. Es ist von Vorteil, das Volumen des verdünnten Würzeablaufs weiter zu verringern, aber dabei muss sorgfältig

darauf geachtet werden, dass keine Luft eingeschleppt oder der Zeitraum der Würzesammlung verlängert wird. Es ist außerdem üblich, die Filterschicht mit dem Aufhacker während des Ablaufens aufzulockern, um das Abfließen der verdünnten Restwürze nach Beendigung der Würzesammlung im Kessel zu beschleunigen. Je aggressiver diese Technik eingesetzt wird, desto mehr feines Material gelangt ins Abwasser. Je mehr verbrauchter Treber nach dem Ablassen zurückbehalten wird, desto mehr Feinteile, die einen CSB bedeuten, bleiben im Senkboden hängen und werden durch die Druckreinigung von der Unterseite des Bodens ins Abwasser eingetragen.

Damit das Abwasser als Prozesswasser für das Maischen wiederverwendet werden kann, müssen die feinen, kolloidalen Teilchen aus der verdünnten Würze entfernt werden. Erreicht werden kann dies durch Zentrifugieren oder eine zweistufige Filtration, d. h. Grobfiltration und anschließende Ultrafiltration. Nach der Grobfiltration wird das Abwasser einem Querstrom-Membranverfahren unterzogen.

#### Erreichbare Umweltvorteile

Geringere Konzentrationen von suspendierten Feststoffen und geringerer CSB im Abwasser.

#### Betriebsdaten

Eine Beispielbrauerei im Vereinigten Königreich hat eine Pilotanlage entwickelt, um besonders stark belastetes Abwasser getrennt vom restlichen Abwasser zu behandeln. Im Läuterbottich entstanden etwa 20 % der gesamten Abwasserbelastung der Brauerei, wie aus Tabelle 4.80 ersichtlich ist.

| Parameter                  | Konzentration                          |                                      | Läuterbottich-<br>Beitrag zur<br>Gesamtfracht<br>(%) |
|----------------------------|--|--------------------------------------|--|
|                            | Brauerei-<br>abwasser gesamt<br>(mg/l) | Läuterbottich-<br>abwasser<br>(mg/l) |  |
| Suspendierte<br>Feststoffe | 800                                    | 6.540                                | 27   |
| CSB                        | 2.000                                  | 13.100                               | 22   |

**Tabelle 4.80: Eigenschaften des Abwassers einer Brauerei**

Bevor mit der Ultrafiltration begonnen werden kann, müssen grobe Teilchen mit einer Größe von mehr als 100  $\mu$  entfernt werden. Etwa 70 % der suspendierten Feststoffe setzen sich leicht ab und sind mit großer Wahrscheinlichkeit durch Grobfiltration zu entfernen. Es wurden versuchsweise verschiedene selbstreinigende Filter in das System eingebaut. Von den in dieser Anlage getesteten Siebgrößen erwies sich bei akzeptablem Wassergehalt (75 % Feuchtigkeit) eine Maschenweite von 30  $\mu$  als optimal für die Feststoffaussiebung. Die Filter waren flexibel genug für die schwankenden Feststofffrachten des Zustroms und lieferten außerdem einen Abfall, der für die Entsorgung zusammen mit dem normalen Treber geeignet war und so nicht einen weiteren Festabfallstrom für die Entsorgung bedeutete.

Nach der Grobfiltration wird das Abwasser einem Querstrom-Membranverfahren unterzogen. Das sich ergebende Konzentrat ist immer noch sehr flüssig und hat einen Feststoffgehalt von weniger als 1 %. Durch eine Beimischung dieses Konzentrats zum normalen Treber mit einem Feuchtigkeitsgehalt von 75 % würde sich der Gesamtfeuchtigkeitsgehalt auf 78 % erhöhen. Für den schlimmsten Fall galt dieser Wert als nicht akzeptabel, und das Konzentrat hätte dann an die Kläranlage abgegeben werden müssen. Der Querstrom-Membranfilter hielt 99 % der suspendierten Feststoffe und 53 % des CSB zurück, sodass ein fünffacher Konzentrationseffekt erzielt wurde.

Im Permeat sind nach der Ultrafiltration die suspendierten Feststoffe um 99 %, die Polyphenole um 45 % und die Lipide (Fette) um 99 % reduziert. Damit kann es Angaben zufolge als 1:3-Ersatz für heißes Maischwasser im Prozess eingesetzt werden. Das führt zu einem Anstieg von 13 mg/l bei den Polyphenolen und 1 mg/l bei den Lipiden. Angaben zufolge sind dies zulässige Prozessschwankungen. Die Frachtreduktion ist in Tabelle 4.81 zusammengefasst.

|                             | Läuterbottichabwasser | Abwasser nach 30-µ-Filter | Ultrafiltration 100 nm |            |
|-----------------------------|-----------------------|---------------------------|------------------------|------------|
|                             |                       |                           | Permeat                | Konzentrat |
| Volumen (m <sup>3</sup> )   | 13                    | 13                        | 10,5                   | 2,5        |
| Feststoffe insgesamt (mg/l) | 6.540                 | 3.110                     | 38                     | 16.010     |
| CSB (mg/l)                  | 13.100                | 13.100                    | 7.623                  | 36.104     |

**Tabelle 4.81: Zusammenfassung der Frachtreduktion bei der Behandlung von Läuterbottichabwasser**

Wirtschaftliche Aspekte

Angaben zufolge geben die meisten Brauereien im Vereinigten Königreich ihr Abwasser zur Behandlung an eine kommunale Kläranlage ab. Dafür werden von der Kläranlage, die gemeinhin einem Wasserunternehmen gehört, Gebühren erhoben. Die Gesamtkosten für die Behandlung des Läuterbottichabwassers werden auf etwa 97 GBP/Brauvorgang geschätzt. Bei 3.000 Brauvorgängen im Jahr bedeutet das Kosten von 291.000 GBP/Jahr.

Durch die geringe CSB-Fracht bei der Abgabe an die kommunale Kläranlage werden die Abwasserkosten um etwa 13 GBP pro Brauvorgang gesenkt. Wenn das Permeat als Maischwasser verwendet wird, kann Heißwasser eingespart werden. Das wird jedoch nur erreicht, wenn die Bilanz der heißen Flüssigkeiten im Sudhaus entsprechend ausfällt. In diesem Fall musste das rückgewonnene heiße Wasser noch durch Zusatzwasser ergänzt werden. Die geschätzte Gesamteinsparung betrug etwa 59 GBP/Brauvorgang oder etwa 176.000 GBP/Jahr. Die jährlichen Betriebskosten wurden auf etwa 28.000 GBP geschätzt, sodass die geschätzte Nettoeinsparung etwa 50.000 GBP betrug. Die Installationskosten beliefen sich auf ungefähr 300.000 GBP, sodass der Amortisationszeitraum auf 2 Jahre geschätzt wurde. Zusätzliche jährliche Einsparungen in Höhe von 50.000 GBP wären möglich, wenn das Konzentrat aus der Ultrafiltration mit dem normalen Treber befrachtet und nicht in die kommunale Kläranlage eingeleitet würde.

Die Kosten einer solchen Anlage können sich von Brauerei zu Brauerei erheblich unterscheiden und sind abhängig von der Größe des Läuterbottichs, den Durchflussraten, dem Bedarf an Puffertanks, dem Entsorgungsweg für Feststoffe und dem Grad der Automatisierung. In der Pilotanlage, von der die vorgestellten wirtschaftlichen Angaben stammen, war die Technik nicht in das automatische Steuersystem der Brauerei integriert und auch nicht mit dem CIP-System verbunden. Auch wenn diese Faktoren die wirtschaftliche Bewertung verändern können, ist den Angaben zufolge eine attraktive finanzielle Amortisationsdauer von 1 bis 2 Jahren für die Implementation des Behandlungssystems für das Läuterbottichabwasser zu erwarten.

Referenzliteratur

[102, UK, 2002]

**4.5.7.8.5 Destillation (Brennereien)**

Angaben zufolge wird in einer Melassebrennerei ein zweistufiges (siehe Abschnitt 4.5.3.3.2) Abwasserbehandlungssystem, bei dem eine anaerobe auf eine aerobe Stufe folgt, eingesetzt. Die Hauptbehandlung erfolgt in einem EGSB-Reaktor (siehe Abschnitt 4.5.3.2.8), in dem die organische Fracht hauptsächlich zu Methangas abgebaut wird, das in der Anlage verwendet werden kann. Es fallen nur geringe Mengen Schlamm an. Der CSB und die Stickstofffracht können dann in einem Belebtschlammreaktor (siehe Abschnitt 4.5.3.1.1) noch weiter reduziert werden.

Abbildung 4.48 zeigt ein Fließdiagramm und den Umfang der anaeroben/aeroben Abwasserbehandlung in einer Brennerei.

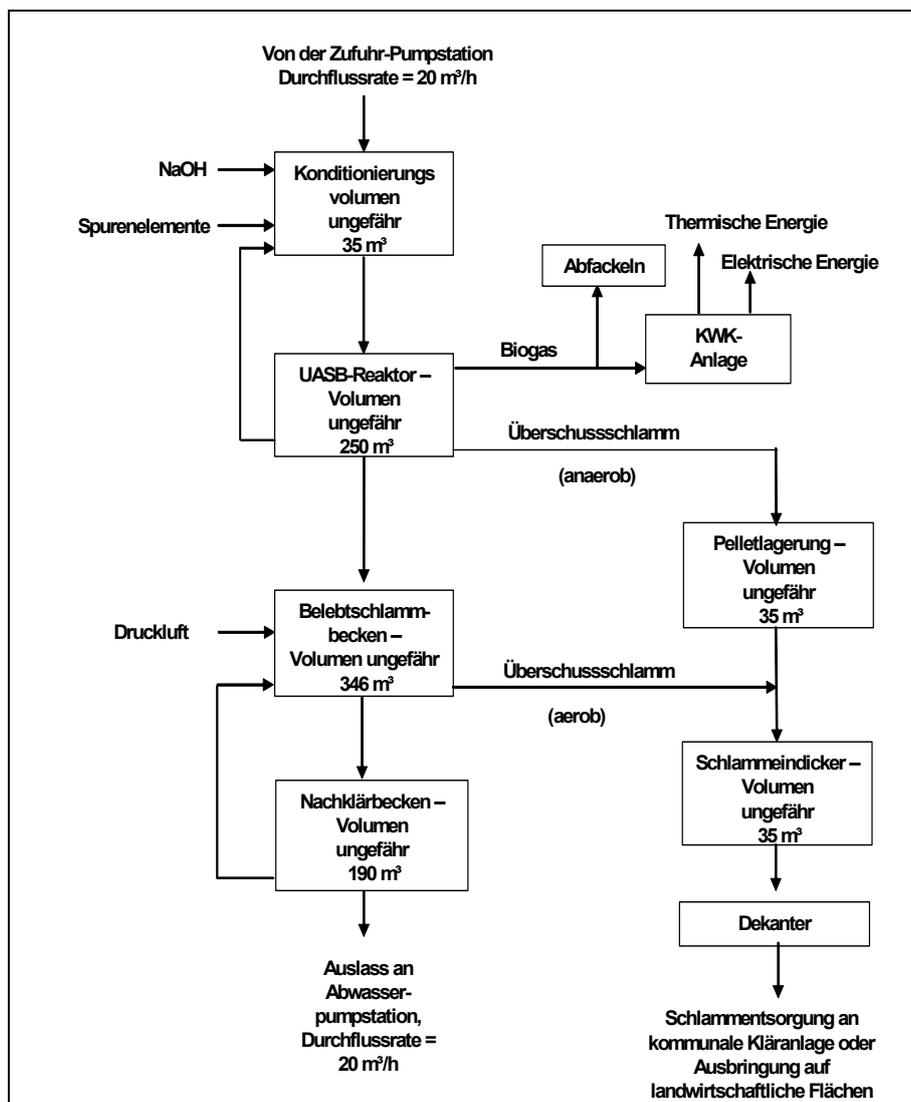


Abbildung 4.48: Anaerobe/aerobe Abwasserbehandlung in einer Brennerei [65, Germany, 2002]

#### 4.5.7.8.6 Wein

Feste Rückstände, z. B. Trauben- oder Tresterrückstände, Filtrerrückstände und Sedimente, die nicht an der Quelle entfernt werden, können durch Sieben/Rechen entzogen werden. Angaben zufolge wird in Weinbergen von der Ausbringung auf landwirtschaftliche Flächen (siehe Abschnitt 4.1.6) und Verdunstungsteichen (siehe Abschnitt 4.5.3.1.4) Gebrauch gemacht.

Die Vorbehandlung dient der Entfernung leicht dekantierbarer suspendierter Feststoffe. Es können folgende Techniken verwendet werden:

- Sieben/Rechen (siehe Abschnitt 4.5.2.1)
- Misch- und Ausgleichsbecken (siehe Abschnitt 4.5.2.3)
- Neutralisation (siehe Abschnitt 4.5.2.4)
- Sedimentation (siehe Abschnitt 4.5.2.5)
- Zentrifugation (siehe Abschnitt 4.5.2.8)
- Fällung (siehe Abschnitt 4.5.2.9)

Nach der Vorbehandlung kann das Wasser, wenn es die Anforderungen erfüllt, in die kommunale Kläranlage eingeleitet oder vor Ort weiterbehandelt werden. Während der weitergehenden Behandlung des Abwassers kann die Hefe ernsthafte Schwierigkeiten verursachen – der Belebtschlamm kann absterben und ausgewaschen werden. Deshalb ist die Abscheidung von Hefe und anderen Feststoffen ein notwendiger Vorbehandlungsschritt.

Anaerobe Verfahren (siehe Abschnitt 4.5.3.2) und insbesondere anaerobe Abwasserteiche (siehe Abschnitt 4.5.3.2.1) und Anaerobfilter (siehe Abschnitt 4.5.3.2.3) sind den Angaben zufolge für die Behandlung von Weinkellereiabwasser am besten geeignet. Alternativ dazu können aerobe Verfahren (siehe Abschnitt 4.5.3.1) benutzt werden. So wird beispielsweise in kleinen Weinkellereien mit geringem Abwasservolumen eine dreimonatige belüftete Lagerung praktiziert. Es werden Belebtschlamm (siehe Abschnitt 4.5.3.1.1) oder Tropfkörper (siehe Abschnitt 4.5.3.1.1) verwendet. Belebtschlammssysteme sind oft aufgrund der jahreszeitlichen Schwankungen überdimensioniert und daher teuer in Installation und Betrieb. Für Tropfkörper wird eine Effizienz von 70 % angegeben, sodass eine weitere Klärung erforderlich ist.

Die nachsorgende Behandlung des Abwassers (siehe Abschnitt 4.5.4) dient als Klärstufe für die Beseitigung der restlichen Verunreinigungen.

### 4.5.7.9 Zitronensäure<sup>31</sup>

Abwasser, das bei der Zitronensäureherstellung anfällt, hat einen hohen CSB. Außerdem enthält es viele Calcium- und Schwefelverbindungen aus der Fällung und dem Abbau und hat eine hohe  $\text{NH}_4\text{-N}$ -Konzentration aus dem Rohstoff (Melasse) und von der Fermentation. Ungefähr 25 % des Rohabwasservolumens sind stark verschmutzt und enthalten etwa 90 % der CSB-Fracht.

Das stark verschmutzte Abwasser wird erst mittels anaerober Fermentation vorbehandelt, wobei Biogas mit einem hohen Schwefelgehalt entsteht. Anschließend werden das im anaeroben Reaktor behandelte Abwasser und die übrigen Abwässer vermischt und weiterbehandelt. Die Konzentrationen im Abwasser pro Tonne der installierten Produktionskapazität nach der Behandlung sind in Tabelle 4.82 angegeben.

| Parameter          | Einheit           | Mittelwert |
|--------------------|-------------------|------------|
| Volumen            | m <sup>3</sup> /t | 40         |
| CSB                | kg/t              | 20         |
| BSB <sub>5</sub>   | kg/t              | 1          |
| NH <sub>4</sub> -N | kg/t              | 0,2        |
| NO <sub>3</sub> -N | kg/t              | 0,08       |
| PO <sub>4</sub> -P | kg/t              | 0,04       |

**Tabelle 4.82: Konzentrationen im Abwasser aus der Zitronensäurefermentation nach der Behandlung pro Tonne der installierten Produktionskapazität [151, Austrian contribution, 2002]**

## 4.6 Vermeidung von Betriebsstörungen

Zu den bedeutendsten Umwelteinflüssen, die mit der Nahrungsmittelproduktion zusammenhängen, zählen Betriebsstörungen, die zur Umweltverschmutzung führen könnten. Dabei handelt es sich meistens um die unbeabsichtigte Freisetzung von Stoffen direkt in die Luft, in das Oberflächengewässer oder in den Boden. Auslöser kann auch ein Versagen von Betriebseinrichtungen sein, das zur Entstehung von ansonsten vermeidbarem Abfall führt. So kann beispielsweise die unbeabsichtigte Freisetzung von Tankinhalten, z. B. von Rohstoffen wie Milch oder Produkten wie Speiseöl oder Hilfsstoffen wie Ammoniak in ein örtliches Gewässer oder für die örtliche Wasserversorgung einen großen Schaden bedeuten. Zu Betriebsstörungen kann es beim Routinebetrieb, aber auch bei Arbeiten außerhalb der Routine kommen.

Es gibt mehrere Stufen beim Umgang mit unbeabsichtigten Freisetzungen, die in den Abschnitten 4.6.1 bis 4.6.6 beschrieben werden. Diese Stufen können folgendermaßen zusammengefasst werden:

- Identifizierung potenzieller Betriebsstörungen, die zu einer Umweltverschmutzung führen könnten
- Durchführung einer Risikoeinschätzung, bei der Eintrittswahrscheinlichkeit und potenzieller spezifischer Umweltschaden (Art und Schweregrad) der identifizierten potenziellen Betriebsstörungen bestimmt werden
- Entwicklung von regulierenden Maßnahmen, mit denen die Risiken, die mit den identifizierten potenziellen Betriebsstörungen verbunden sind, verhindert, beseitigt oder auf ein akzeptables Maß reduziert werden können

<sup>31</sup> Anm. d. UBA-Bearb.: Wird in Deutschland nicht mehr hergestellt und kommt nahezu komplett aus China nach Europa.

- Entwicklung und Umsetzung eines Notfallplans
- Untersuchung sämtlicher Betriebsstörungen und Beinahe-Betriebsstörungen, damit die jeweiligen Ursachen festgestellt und Maßnahmen zur Vermeidung von Wiederholungen ergriffen werden können.

#### 4.6.1 Typische Betriebsstörungen

##### Beschreibung

Betriebsstörungen können beispielsweise folgende Ursachen haben:

- Freisetzungen aus Großraumlagern, z. B. Leckagen, Verschüttungen und Behälterversagen
- Freisetzungen durch Versagen von Prozesssteuerungen
- Versagen oder Fehlfunktionen von nachsorgenden Verminderungstechniken
- Versagen von z. B. Wasser- oder Stromversorgung.

Die Informationen über die identifizierten potenziellen Betriebsstörungen können dann zur Risikoeinschätzung (siehe Abschnitt 4.6.2) genutzt werden.

Zu den nützlichen Informationen zählen beispielsweise:

##### (a) Angaben über am Standort vorhandene Stoffe

Das Unfallpotenzial wird wesentlich beeinflusst von den am Standort vorhandenen Rohstoffen, Hilfsstoffen, Zwischenprodukten, Produkten und Abfällen. Daher sind folgende Maßnahmen wichtig:

- Führen einer Inventarliste der Stoffe. Möglicherweise ist gesetzlich vorgeschrieben, diese Liste Notfallhelfern zur Verfügung zu stellen
- Einschätzung der möglichen Umwelt- und Sicherheitsgefahren durch diese Stoffe. Eine gute Quelle für Sicherheits- und Umweltangaben sind Sicherheitsdatenblätter, die vom Hersteller der Stoffe mitgeliefert werden, und Produktdatenblätter, die normalerweise unternehmensintern erstellt werden
- Angaben zu am Standort gelagerten Mengen und deren Lagerort.

##### (b) Identifizierung der Emissionen bei den verschiedenen Arbeitsverfahren/Emissionsverzeichnis

Es ist wichtig, sämtliche Ströme/Emissionen oder potenziellen Ströme/Emissionen zu identifizieren, aus denen sich ungewöhnliche/unbeabsichtigte Freisetzungen ergeben können.

Am systematischsten lässt sich dies bewerkstelligen, indem jeder einzelne Prozess durchgegangen wird und alle zugehörigen potenziellen Emissionen identifiziert werden. Dazu zählen normalerweise:

- Anlieferung von Rohmaterial
- Massenslagerung von Rohmaterial
- Rohstofflagerung in kleineren Mengen, Flüssigei-Fässer, Säcke, Kippsilobehälter
- Produktion
- Verpackung
- Palettierung
- Lagerung.

Nicht nur die Prozesse selbst, sondern auch Hilfsgeräte/-prozesse am Standort müssen berücksichtigt werden. Dazu zählen normalerweise:

- Versorgungseinrichtungen wie Kesselhaus, Druckluft-, Wasserbehandlungs- und Ammoniaksysteme
- anlageninterner Verkehr und Transport, z. B. Gabelstapler.

Mögliche Szenarien, die zu einem unbeabsichtigten plötzlichen Anstieg der Lärmemissionen an den Standortgrenzen führen können, sind ebenfalls zu berücksichtigen.

##### (c) Lageplan der Anlage/des Standorts

Dieser Plan zeigt das bereits vorhandene Drainagesystem des Standorts und Vermeidungsmaßnahmen, die Positionen von Schüttgut- und Fasslagereinrichtungen für Stoffe, die in Großmengen gelagert werden oder beson-

ders gefährlich sind, Transportsysteme wie Rohrleitungen für Gefahrstoffe, wichtige Luftemissionspunkte und empfindliche Grenzen und Eintragsgebiete. Dieser Plan muss immer auf dem neuesten Stand gehalten werden.

### (d) Position, bezogen auf Eintragsgebiete

Je nachdem, welcher Stoff bei einem Unfall freigesetzt wird, kann der Schaden als umfassendes Problem betrachtet werden oder die Verschmutzungsauswirkung auf einen Bereich in unmittelbarer Anlagennähe begrenzt sein. Zum Verständnis der potenziellen Umweltauswirkungen einer unbeabsichtigten Freisetzung muss die örtliche Umweltsituation bekannt sein. Zwar bestehen Ähnlichkeiten zwischen den Standorten, aber es wird auch immer Unterschiede geben, z. B. bei den Umweltsituationen von Anlagen in ländlichen, in Wohn- und Industriegebieten. Unbeabsichtigte Freisetzungen von Luftemissionen und ein plötzlicher Anstieg des Lärmpegels sind wahrscheinlich für Anlagen in der Nähe von Wohngebieten von Bedeutung, während die Auswirkungen auf örtliche Wasserläufe und die jeweilige Fauna in ländlichen Gebieten eine wichtigere Rolle spielen. Öffentliche Erholungsgebiete müssen berücksichtigt werden, insbesondere wenn Oberflächenwasser oder behandeltes Abwasser in Flüsse eingeleitet wird und wenn das Risiko einer Grundwasserkontamination besteht.

Außerdem ist ein grundlegendes Verständnis der Geologie und Hydrologie des Gebietes nützlich, in dem die Anlage steht. Auf Lehmböden dauert es länger, bis ausgelaufene Stoffe ins Grundwasser gelangen, als auf Sand- oder durchlässigen Böden.

Mit einer Standorterhebung ist es möglich, sämtliche Eintragsgebiete zu erfassen und festzustellen, welche davon besonders empfindlich sind, z. B.

- Wasserläufe, in die behandeltes Wasser und/oder Oberflächenwasser eingeleitet wird
- Wohnhäuser an der Standortgrenze
- örtliche Touristenattraktionen, die an den Standort grenzen
- örtliche Schulen/Krankenhäuser
- empfindliche Grundwasserleiter
- Orte von besonderer wissenschaftlicher Bedeutung
- außergewöhnliche Naturschönheiten.

### (e) Geschichte des Standorts

Ziel der Dokumentation der Standortgeschichte ist der Nachweis, dass sich an einem Standort keine durch frühere Aktivitäten verursachten Umweltprobleme ergeben können. Die gesammelten Angaben können auch eine Basis für die Bewertung der Auswirkungen möglicher zukünftiger unbeabsichtigter Freisetzungen bilden.

Die Hauptfrage dabei bezieht sich meist auf kontaminierte Böden oder kontaminiertes Grundwasser. Die Kontaminationen können durch Quellen wie unterirdische Lagertanks, mangelhafte Auffangbecken und Überlaufschutzvorrichtungen, Standortdeponien oder leckende Abläufe bedingt sein. Durch die Dokumentation früherer Standortnutzungen lassen sich Bereiche erkennen, in denen es möglicherweise Kontaminationen gegeben hat, und es können ggf. entsprechende Untersuchungen mittels Boden- und Grundwasserbeprobung und -analyse erfolgen. Untersuchungen dieser Art werden normalerweise nur dann durchgeführt, wenn Grund zu der Annahme besteht, dass Böden oder Grundwasser kontaminiert sind.

### (f) Sonstige Angaben

Andere Faktoren, die zur Erkennung potenzieller Quellen für umweltrelevante Vorfälle beitragen können, sind u. a.:

- frühere Vorfälle einschließlich von Beinahe-Betriebsstörungen
- technische und administrative/operative Steuerungen und deren mögliches Versagen
- menschliches Verhalten, die Zusammenarbeit zwischen Bedienern und Herstellungsbetrieben und mögliche Umweltvorfälle, die durch menschliches Verhalten ausgelöst werden.

### (g) Strukturierte Techniken

Zur Identifizierung potenzieller Unfälle können strukturierte Techniken eingesetzt werden. Bei diesen Techniken werden Flussdiagramme der betrachteten Herstellungsverfahren genauestens untersucht. HAZOPS

(Hazard and Operability Studies), FMEA (Fehlermöglichkeits- und Einfluss-Analysen) und SWIFT (Structured What-IF Techniques) sind Beispiele für solche Methoden. Diese Techniken können viel Zeit und Ressourcen in Anspruch nehmen und werden üblicherweise nicht in Anlagen mit relativ einfachen Prozessen und Arbeitsgängen eingesetzt.

#### Erreichbare Umweltvorteile

Geringeres Risiko von Betriebsstörungen, die zu einer Umweltverschmutzung führen können.

#### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion. Allerdings gilt, dass bereits im Planungsstadium einer Anlage erkannte mögliche Unfälle leichter und kostengünstiger verhindert werden können, als wenn später entsprechende Maßnahmen ergriffen werden.

#### Anlass für die Umsetzung

Geringeres Risiko von Betriebsstörungen, die zu einer Umweltverschmutzung führen können.

#### Beispielanlagen

Weit verbreitet.

## 4.6.2 Risikobewertung

### Beschreibung

Risikobewertungen sind ein wichtiger Teil der Managementverfahren, da es die Anwendung dieser Technik ist, die darüber entscheidet, ob die Führungsebene ein erhebliches Unfallrisiko für gegeben hält.

Art und Ausführlichkeit der Risikobewertung hängen von Eigenschaften und Lage des Standorts ab. Art und Größenordnung der Tätigkeiten, die in der betrachteten Anlage durchgeführt werden, sowie die Risiken für Mensch und Umwelt müssen berücksichtigt werden.

Eine Gefahr ist alles, was potenziell Schaden verursachen kann. Ein Risiko ist die Wahrscheinlichkeit dafür, dass eine Gefahr einen spezifischen Schaden bei Personen oder Dingen verursacht. Es gibt also an, ob die Chancen dafür, dass der Schaden durch die Gefahr verursacht wird, groß oder gering sind.

#### (a) Schwere

Einige Beispiele für Schweregrade auf einer Skala von 0 bis 4, bei der 4 für den höchsten Schweregrad steht, sind:

- Eine Verschüttung von Feststoffen in der Anlage, die vollständig eingegrenzt werden kann, bei der die Verschüttung wieder verwendet werden kann und bei der kein Umweltschaden auftritt, würde mit 0 bewertet.
- Wenn die Verschüttung zu einer sehr kurzfristigen und geringfügigen Kontamination eines Teils des Bodens am Standort führen würde, würde sie mit 1 bewertet. Wenn jedoch die Verschüttung das Grundwasser erreichen würde und zu einem Schaden auf regionaler Ebene durch Verunreinigung von Wasserquellen führen könnte, läge die Bewertung zwischen 2 und 4, je nach Schadstoff, betreffenden Mengen und der Empfindlichkeit des Grundwassers, also z. B. dessen Verwendung als Trinkwasserquelle.
- Wenn die Verschüttung in das Oberflächenwasserablaufsystem einträte, könnte es zu geringen, mäßigen oder großen Schäden der lokalen Umwelt kommen. Je nach Größenordnung und Toxizität dieser Freisetzung würde das einen Wert von 2, 3 oder 4 bedeuten.

#### (b) Wahrscheinlichkeit

Die Eintrittswahrscheinlichkeit hängt davon ab, ob alle nötigen Vorsichtsmaßnahmen, z. B. wie sie gesetzlich vorgeschrieben oder als nationaler, internationaler oder Industriestandard angesehen werden, bereits für die Prozesse und Arbeitsabläufe in der Anlage vorhanden sind und gepflegt werden. Auch die Wahrscheinlichkeit kann mit einer Skala, z. B. von 1 bis 5, bewertet werden, auf der 5 der höchsten Wahrscheinlichkeit entspricht.

#### (c) Gesamtrisikobewertung

Das Gesamtrisiko berechnet sich dann durch die Multiplikation von Schwere(grad) mit Wahrscheinlichkeit.

Die Durchführung einer Bewertung ermöglicht eine systematische Untersuchung der möglichen Betriebsstörungen. Dadurch lassen sich Prioritäten bei den Maßnahmen zur Risikovermeidung setzen, indem sichergestellt wird, dass die wichtigsten Risiken zuerst in Angriff genommen werden.

### Erreichbare Umweltvorteile

Geringeres Risiko von Betriebsstörungen, die zu einer Umweltverschmutzung führen können.

### Betriebsdaten

Risikobewertungen sind nicht mehr aktuell, sobald Änderungen in der Technik oder den Betriebsbedingungen stattfinden. Damit sie effektiv sind, müssen sie regelmäßig aktualisiert werden, und auch dann, wenn wesentliche Änderungen in der Anlage eintreten, z. B. bei Einführung neuer Arbeitsgänge.

Die öffentliche Wahrnehmung entspricht nicht unbedingt dem tatsächlichen Umweltschaden oder der Einhaltung gesetzlicher Auflagen. Sie lässt sich besser anhand der Anzahl der Beschwerden aus der Öffentlichkeit und von Aufsichtsbehörden einschätzen, sowie anhand des Interesses, das diese Parteien an den Aktivitäten in der Anlage zeigen.

### Anwendbarkeit

In neuen und bereits bestehenden Anlagen der Nahrungsmittelproduktion anwendbar.

### Anlass für die Umsetzung

Geringeres Risiko von Betriebsstörungen, die zu einer Umweltverschmutzung führen können.

### Beispielanlagen

Weit verbreitet.

## **4.6.3 Typisierung von potenziellen Betriebsstörungen, die verhindert werden müssen**

### Beschreibung

Nach Abschluss der Risikobewertungen müssen diejenigen Betriebsstörungen identifiziert werden, die wesentliche Umweltauswirkungen haben könnten und die derzeit nicht angemessen vermieden/verhindert werden. Dazu werden die Ergebnisse der Risikobewertung herangezogen. Das Bewertungssystem kann dazu genutzt werden, vordringliche Maßnahmen zu identifizieren. Im Laufe der Zeit können sie sich als Teil eines kontinuierlichen Programms zur Verbesserung der Umweltsituation ändern.

### Erreichbare Umweltvorteile

Geringeres Risiko von Betriebsstörungen, die zu einer Umweltverschmutzung führen können.

### Anwendbarkeit

Anwendbar in allen Anlagen der Nahrungsmittelproduktion. Allerdings gilt, dass bereits im Planungsstadium einer Anlage erkannte mögliche Unfälle leichter und kostengünstiger verhindert werden können, als wenn später entsprechende Maßnahmen ergriffen werden.

### Anlass für die Umsetzung

Geringeres Risiko von Betriebsstörungen, die zu einer Umweltverschmutzung führen können.

### Beispielanlagen

Weit verbreitet.

## **4.6.4 Identifizierung und Umsetzung der erforderlichen Vorbeuge- und Vermeidungsmaßnahmen**

### Beschreibung

Die erkannten möglichen Quellen/Ursachen für Unfälle müssen untersucht werden, um festzustellen, ob neue Vorbeuge- und Vermeidungsmaßnahmen erforderlich sind oder bestehende Maßnahmen verbessert werden müssen.

Solche Maßnahmen können z. B. sein:

- Managementverfahren
- Operative Verfahren
- Vorbeugungstechniken
- Eindämmung
- Prozessplanung/Prozesssteuerung.

(a) Managementverfahren

Es können Managementverfahren eingeführt werden, mit denen neue Aktivitäten am Standort bewertet werden. Dadurch soll sichergestellt werden, dass Umweltaspekte wie die Möglichkeit unbeabsichtigter Freisetzungen berücksichtigt werden. Solche Verfahren sind beispielsweise:

- Verfahren zur Umweltrisikobewertung bei neuen Rohstoffen
- Gewährleistung ausreichender Vorbeuge- und Vermeidungsmaßnahmen
- Überprüfung der Verträglichkeit mit anderen Stoffen und Lagerbeständen, mit denen diese unbeabsichtigt in Berührung kommen können
- Einführung von Verfahren, nach denen neue Prozesse bewertet werden, um zu gewährleisten, dass Vorbeuge- und Vermeidungsmaßnahmen zur Verhinderung oder Minimierung unbeabsichtigter Freisetzung bereits bei der Planung vorgesehen werden

(b) Operative Verfahren

Es müssen operative Verfahren entwickelt werden, die wichtige Aspekte von Prozessanlagen abdecken, damit eine Minimierung des Unfallrisikos gewährleistet ist.

Die Bedieneranweisungen für die Prozessanlage umfassen z. B.:

- Durchführung von Routineprüfungen an möglichen Quellen unbeabsichtigter Freisetzungen und sämtlicher vorhandenen Vorbeuge- und Vermeidungsmaßnahmen
- Durchführung regelmäßiger Überprüfungen von Verschmutzungsvermeidungseinrichtungen wie Schlauchfilter, Zyklone und Abfallbehandlungsanlagen
- Durchführung regelmäßiger Inspektionen bei unterirdischen Lagertanks und Auffangbecken.

(c) Vorbeugende Techniken

Ein Beispiel:

- Einbau geeigneter Barrieren zur Vermeidung von Geräteschäden durch Fahrzeugbewegungen

(d) Eindämmung

Solche Verfahren können unter anderem sein:

- Auffangbecken für Massengutlagerung
- Verwendung von Reinigungsgeräten zur Minimierung der Auswirkungen unbeabsichtigter Freisetzungen
- Isolierung von Abläufen
- Eindämmung oder Vermeidung unbeabsichtigter Freisetzungen aus Sicherheitsventilen oder Berstscheiben

(e) Prozessplanung/Prozesssteuerung

Prozessanlagen müssen so geplant und gesteuert werden, dass das Risiko einer unbeabsichtigten Stofffreisetzung entweder eliminiert oder auf ein akzeptables Niveau gesenkt wird.

Maßnahmen zur Prozessplanung/Prozesssteuerung sind beispielsweise:

- Anwendung von Techniken zur Überwachung der Effizienz von Vermeidungseinrichtungen, z. B. des Druckverlusts bei Schlauchfiltern
- Anwendung von Techniken zur Vermeidung der Überfüllung von Speichertanks, z. B. Füllstandsmessung, Warnsignale und Sperrsteuerungen für hohe Füllstände

### Erreichbare Umweltvorteile

Geringeres Risiko von Betriebsstörungen, die zu einer Umweltverschmutzung führen können.

### Anwendbarkeit

In allen neuen und bereits bestehenden Anlagen der Nahrungsmittelproduktion anwendbar.

### Anlass für die Umsetzung

Geringeres Risiko von Betriebsstörungen, die zu einer Umweltverschmutzung führen können.

### Beispielanlagen

Weit verbreitet.

## 4.6.5 Entwicklung, Umsetzung und Tests von Notfallplänen

### Beschreibung

Es müssen Notfallmaßnahmen/-pläne entwickelt und umgesetzt werden, damit für den Fall eines Vorkommnisses gewährleistet ist, dass die Normalsituation mit minimalen Auswirkungen auf die Umwelt wiederhergestellt werden kann. Wenn der Plan nicht getestet wird, funktioniert er im Bedarfsfall möglicherweise nicht. Wenn sich die Bedingungen am Standort oder Zuständigkeiten ändern, muss der Notfallplan überarbeitet werden.

Normalerweise werden Notfallpläne für den gesamten Standort entworfen und decken Sicherheits- und wichtige Umweltrisiken ab. Notfallmaßnahmen, die sich mit den identifizierten wichtigen Umweltrisiken befassen, können dann in den Gesamtnotfallplan eingebaut werden.

Ein normaler Notfallplan, der Umweltvorfälle abdeckt, hat die folgenden Komponenten:

- Rollen und Verantwortlichkeiten von Personen müssen eindeutig definiert werden. Dazu gehören:
  - Maßnahmen für Bediener, die zurückbleiben, um wichtige Arbeitsgänge zu bedienen
  - Fluchtverfahren und -wege
  - Verfahren, mit denen der Verbleib sämtlicher Mitarbeiter überprüft werden kann
- Zuweisung von Rettungs- und medizinischen Versorgungsaufgaben
- Verfahren zur Meldung von Notfällen und zur Verständigung der zuständigen Umweltbehörden und von Notfalldiensten müssen vorgesehen/abgestimmt werden
- Auswirkungen von Umweltbeeinträchtigungen sind aktiv zu minimieren
- Die Namen der Mitarbeiter müssen aufgeführt werden.

Beispielsweise wird empfohlen, dass Notfallmaßnahmen vorhanden sind, die Vorfälle abdecken, bei denen unbeabsichtigt folgende Substanzen freigesetzt werden:

- Ammoniak
- flüssige Rohstoffe oder Produkte, die in großen Mengen gelagert werden, z. B. Speiseöl und Milch
- Staub aus Trocknungsvorgängen wie der Sprühtrocknung
- potenziell gefährliche Hilfsstoffe wie Biozide und Dieselöl.

Hauptziel eines Notfallplans ist es, den Normalzustand so schnell wie möglich und mit möglichst geringen Auswirkungen auf die Umwelt wiederherzustellen. Notfallsituationen können sich nach Größenordnung und Komplexität sehr stark unterscheiden, und es ist wichtig, dass Notfallpläne flexibel genug sind, um sowohl bei kleineren als auch bei größeren Vorkommnissen effizient zu sein. Außerdem müssen sie einfach genug sein, um schnell umgesetzt werden zu können.

Die Auswirkungen potenzieller Katastrophenfälle können erheblich eingeschränkt werden, wenn Pläne systematisch vorbereitet und regelmäßig gründlich überprüft sowie Mitarbeiter informiert und geschult werden. Im Notfall reicht die Zeit nicht aus, um zu entscheiden, wer verantwortlich ist, um bei auswärtigen Ämtern zu erfragen, wo Hilfe erreichbar ist, oder um Personen auf den Notfalleinsatz vorzubereiten. Alle diese Dinge müssen erledigt werden, bevor ein Notfall eintritt.

Weitere Gründe für die Ausarbeitung von Notfallplänen sind beispielsweise:

- durch Verkürzung der Reaktionszeit (Überlegungszeit) nach einem Unfall können dessen Folgen erheblich gemindert werden, z. B. was Verletzungen, Beschädigungen, Umweltauswirkungen und Geschäftsausfälle angeht
- damit keine chaotischen Zustände eintreten, sondern ein ordentlicher Ablauf gewährleistet ist
- damit ein schlechtes Bild in der Öffentlichkeit vermieden wird, denn durch schwere Betriebsstörungen kann der Ruf eines Unternehmens und auch sein Absatz beeinträchtigt werden
- die Erfüllung gesetzlicher Anforderungen. In vielen Ländern sind Notfallpläne vorgeschrieben
- damit Vorbereitungen für die Benachrichtigung von externen Behörden, der allgemeinen Öffentlichkeit, der Medien und der Unternehmensleitung getroffen werden können.

Mit dem Notfallplan kann auch gewährleistet werden, dass geeignete Vorbeuge- und Vermeidungsmaßnahmen vorhanden sind, um die Folgen eines Unfalls abzumildern, z. B. Gerätschaften zur Beseitigung von ausgelaufenem Öl, die Isolierung von Abflüssen, die Benachrichtigung der zuständigen Behörden, Evakuierungsverfahren usw.

#### Erreichbare Umweltvorteile

Minimierung der durch Unfälle verursachten Verschmutzung.

#### Anwendbarkeit

Anwendbar, wo ein erhebliches Verschmutzungsrisiko durch Unfälle besteht.

#### Anlass für die Umsetzung

Minimierung der Umweltbeeinträchtigung durch Betriebsstörungen, Begrenzung der Rufschädigung eines Unternehmens durch eine Betriebsstörung und Eingrenzung der verschiedenen Kosten, die für die Sanierung des Standorts, Strafgeelder und Haftungsübernahmen entstehen.

#### Beispielanlagen

Weit verbreitet.

### **4.6.6 Untersuchung sämtlicher Betriebsstörungen und Beinahe-Betriebsstörungen**

#### Beschreibung

Aus der Untersuchung sämtlicher Betriebsstörungen und Beinahe-Betriebsstörungen können Schlüsse für die Zukunft gezogen werden. Die Ursachen für eingetretene Betriebsstörungen und Beinahe-Betriebsstörungen können identifiziert und Maßnahmen ergriffen werden, um Wiederholungen zu vermeiden. Wenn Beinahe-Betriebsstörungen nicht untersucht werden, geht möglicherweise die Gelegenheit zur Verhinderung einer Betriebsstörung verloren. Das Führen entsprechender Unterlagen kann dazu beitragen, dass Maßnahmen ergriffen und Vorbeugemaßnahmen beibehalten werden.

#### Erreichbare Umweltvorteile

Geringeres Risiko von Betriebsstörungen, die zu einer Umweltverschmutzung führen können.

#### Betriebsdaten

Ein Beispiel für eine Beinahe-Betriebsstörung ist es, wenn ein offengebliebenes Ventil an einem leeren Vorratstank rechtzeitig bemerkt wird, sodass es vor der Neubefüllung geschlossen werden kann. Durch die Einführung einer technischen oder operativen Lösung kann einer künftig möglichen Betriebsstörung vorgebeugt werden, die darin besteht, dass etwa Flüssigkeiten in einen offenen Tank und damit direkt in die Kläranlage gepumpt werden oder im Hof auslaufen und dann in das Oberflächen- und/oder Grundwasser gelangen. So werden sowohl die unbeabsichtigte Freisetzung als auch die Abfallentstehung vermieden.

#### Anwendbarkeit

In allen neuen und bereits bestehenden Anlagen der Nahrungsmittelproduktion anwendbar.

#### Anlass für die Umsetzung

Geringeres Risiko von Betriebsstörungen, die zu einer Umweltverschmutzung führen können.

#### Beispielanlagen

Weit verbreitet.

## 4.7 Techniken, die in bestimmten Einzelbranchen anwendbar sind

### 4.7.1 Fleisch und Geflügel

#### 4.7.1.1 Trennung der anfallenden Stoffe zur Optimierung von Verbrauch, Wiederverwendung, Rückgewinnung, Wiederverwertung und Entsorgung (sowie zur Minimierung von Wasserverbrauch und Abwasserverunreinigung)

Diese Technik wird in Abschnitt 4.1.7.6 beschrieben.

##### Dokumentierte Beispiele für die Anwendung der Technik

Es gibt wahrscheinlich noch zahlreiche andere Möglichkeiten, wie diese Technik innerhalb der Branche eingesetzt werden kann.

- trockene Sammlung aller festen Abfälle in Schalen oder Körben, damit diese nicht auf den Boden fallen und in die Kläranlage gelangen
- viele Rohstoffe werden in offenen Bottichen oder Wagen transportiert/gelagert. In diesen Behältern sammelt sich am Boden eine erhebliche Menge an Fleischsaft. Anstatt diesen Fleischsaft in die Kläranlage einzuleiten und dadurch die Verschmutzung des Abwassers zu verstärken, kann er bei der Herstellung von verarbeiteten Fleischprodukten verwendet werden
- Zerteilungs- und Entbeinungsvorgänge finden meist nach dem Kühlen statt. Nach dem Kühlen lassen sich die Schlachtkörper leichter handhaben, zerlegen und entbeinen. Die Knochen werden vom Fleisch getrennt und zusammen mit Fleischresten und Fetten, die nicht für den menschlichen Verzehr bestimmt sind, in an den Geräten befestigten Schalen gesammelt und zur Behandlung oder Entsorgung an Verarbeitungsbetriebe für tierische Nebenprodukte abgegeben.

##### Anwendbarkeit

Anwendbar in Anlagen der Fleischproduktion.

##### Referenzliteratur

[41, Nordic Council of Ministers, 2001]

#### 4.7.1.2 Trockenreinigung

Diese Technik wird in Abschnitt 4.3.1 beschrieben.

##### Dokumentierte Beispiele für die Anwendung der Technik

Es gibt wahrscheinlich noch zahlreiche andere Möglichkeiten, wie diese Technik innerhalb der Branche eingesetzt werden kann.

- Wenn Hackfleischreste, insbesondere Fleischmischungen für die Salami- oder Wurstherstellung in Geräten wie Kuttern und Wurstfüllmaschinen sowie auf Fußböden, nicht entfernt werden, kleben sie an den Oberflächen fest und erschweren die spätere Reinigung. Wenn diese Geräte unmittelbar nach dem Produktionsende gereinigt werden, lassen sich Reinigungsanstrengung, Wasser- und Reinigungsmittelbedarf minimieren. Soweit praktisch möglich, werden die Hackfleischreste vor der Reinigung manuell entfernt und zur Verwertung weitergegeben
- Wenn bei Putz- und Zerlegungsarbeiten Fleischreste mit trockenen Reinigungsverfahren beseitigt werden, sinkt die Verschmutzungsfracht des Abwassers
- Montage von Abdeckungen an Abläufen, deren Löcher so klein sind, dass Fleischreste nicht in die Kläranlage gelangen.

##### Anwendbarkeit

Anwendbar in Anlagen der Fleischproduktion.

##### Referenzliteratur

[41, Nordic Council of Ministers, 2001]

### 4.7.1.3 Minimierung der Produktion und Verwendung von Scherbeneis

#### Beschreibung

Bei der Verarbeitung von Hackfleisch wird das Fleischgemisch oft mit Scherbeneis gekühlt. Mit einer geeigneten Mischung aus gekühlten und gefrorenen Rohstoffen kann die Verwendung und damit die Herstellung von Scherbeneis vermieden werden. Manchmal wird Scherbeneis zugesetzt, wenn Prozesse wie das Hacken die Temperatur ansteigen lassen und damit die Hygiene oder Produktqualität gefährden, oder wenn nur eine geringe Wassermenge zum Produkt zugegeben werden muss.

#### Erreichbare Umweltvorteile

Geringerer Wasser- und Energieverbrauch.

#### Anwendbarkeit

Anwendbar in der Hackfleischverarbeitung.

#### Referenzliteratur

[41, Nordic Council of Ministers, 2001]

## 4.7.2 Fisch und Schalentiere

### 4.7.2.1 Trennung der anfallenden Stoffe zur Optimierung von Verbrauch, Wiederverwendung, Rückgewinnung, Wiederverwertung und Entsorgung (sowie zur Minimierung von Wasserverbrauch und Abwasserunreinigung)

Diese Technik wird in Abschnitt 4.1.7.6 beschrieben.

#### Dokumentiertes Beispiel für die Anwendung der Technik

Es gibt wahrscheinlich noch zahlreiche andere Möglichkeiten, wie diese Technik innerhalb der Branche eingesetzt werden kann.

- Trockene Sammlung aller festen Abfälle in Schalen oder Körben, damit diese nicht auf den Boden fallen und in die Kläranlage gelangen.

#### Anwendbarkeit

Anwendbar in allen Anlagen, die Fisch und Meeresfrüchte verarbeiten.

#### Referenzliteratur

[134, AWARENET, 2002]

### 4.7.2.2 Trockenreinigung

Diese Technik wird in Abschnitt 4.3.1 beschrieben.

#### Dokumentiertes Beispiel für die Anwendung der Technik

Es gibt wahrscheinlich noch zahlreiche andere Möglichkeiten, wie diese Technik innerhalb der Branche eingesetzt werden kann.

- Trockensammelsysteme für Festabfall von Krustentieren und Weichtieren, wie Siebe und effiziente Rückgewinnungssysteme, verhindern, dass diese in die Kläranlage gelangen. Angaben zufolge können sie zu einer Senkung des BSB<sub>5</sub> um bis zu 35 % führen.

#### Anwendbarkeit

Anwendbar in allen Anlagen, die Fisch und Meeresfrüchte verarbeiten.

#### Referenzliteratur

[134, AWARENET, 2002]

### 4.7.2.3 Ausschließliche Verwertung von qualitativ hochwertigem Fisch

#### Beschreibung

Wenn die Fischqualität mangelhaft ist, können weiche Filets im Enthäutungsmesser hängenbleiben. Dadurch sinkt die Ausbeute des Prozesses und es fallen größere Mengen an Nebenprodukten und Abfall an. Beim Enthäuten von fettem Fisch gelange große Mengen Öl ins Abwasser und verursachen etwa ein Drittel des gesamten CSB. Zur Reinigung und zum Schmieren der Geräte wird Wasser gebraucht. Auch das regelmäßige Schärfen der Enthäutungsmesser trägt erheblich zur effizienten Enthäutung und Abfallminimierung bei.

Unter den anaeroben Bedingungen, die bei der Lagerung im Fischereifahrzeug herrschen, kann Fisch schlecht werden, sodass die schnelle Ablieferung und Verarbeitung sowie qualitätserhaltende Lagerbedingungen zur Wahrung einer hohen Qualität beitragen. Fisch wird auf See in Eis gelagert. An Land erfolgt die Lagerung entweder auf Eis oder in Kühllagern. Die Lagermethode kann davon abhängen, wieviel Zeit zwischen Fischfang und anschließender Verarbeitung vergeht (siehe auch Abschnitt 4.1.7.3). Hochwertiger Fisch kann für Filets ausgewählt und minderwertiger Fisch z. B. für die Herstellung von Fischmehl und Fischöl verwendet werden. Beschädigte Fische können für Nahrungsmittel verwendet werden, für die keine ganzen Filets erforderlich sind, wie beispielsweise Formfischprodukte und Suppen.

Die erfolgreiche Anwendung dieser Technik hängt von der Zusammenarbeit mit den Betreibern der Fischereifahrzeuge und den Zwischenlagerern des Fisches (Großhändler, Transportunternehmen) ab.

#### Erreichbare Umweltvorteile

Weniger Abfall.

#### Medienübergreifende Auswirkungen

Für die Lagerung kann Energie verbraucht werden.

#### Anwendbarkeit

In der Fischverarbeitung anwendbar.

#### Anlass für die Umsetzung

Weniger Abfall.

#### Referenzliteratur

[28, Nordic Council of Ministers, 1997, 134, AWARENET, 2002]

### 4.7.2.4 Abtransport von Haut und Fett aus der Enthäutungstrommel mittels Vakuum

#### Beschreibung

Diese Technik besteht aus einer Saugvorrichtung, die Haut und Fett aus der Enthäutungstrommel absaugt. Wasser wird nur verwendet, um die Trommel zu befeuchten und den Saugeffekt aufrechtzuerhalten.

#### Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs. Geringere Verschmutzung des Abwassers.

#### Medienübergreifende Auswirkungen

Energieverbrauch.

#### Betriebsdaten

Sowohl die CSB-Fracht als auch der Wasserverbrauch werden um 95 – 98 % reduziert. Der Wasserbedarf für Transport und Routinespülungen entfällt.

#### Anwendbarkeit

Anwendbar im Fischsektor, z. B. während des Enthäutens.

#### Wirtschaftliche Aspekte

Einsparungen bei der Abwasserbehandlung.

#### Beispielanlagen

Anwendung in der dänischen Heringsindustrie (siehe Abschnitt 4.7.2.9.1).

Referenzliteratur

[Nordic Council of Ministers, 1997 #28; Ministry for the Environment, 2001]

**4.7.2.5 Entfernung und Abtransport des Fettes und der Eingeweide durch Absaugung**Beschreibung

Beim Enthäuten und Zerlegen werden geschlossene System für den Transport von Fett und Eingeweiden zu Sammelstellen verwendet. Fett und Eingeweide werden durch Absaugen (Vakuum), nicht durch Wasser von den Fischen getrennt. Die Absaugvorrichtung besteht aus einem Vakuum, das in eine eigens entwickelte Absaugdüse mündet, die unmittelbar hinter dem Kopfeinschnitt platziert wird.

Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs. Geringere Verschmutzung des Abwassers. Abfallminimierung, z. B. können Nebenprodukte für die Fischmehlproduktion verkauft werden.

Medienübergreifende Auswirkungen

Energieverbrauch und Lärmverschmutzung.

Betriebsdaten

Es werden Rückgänge der Verschmutzungsfracht um 30 – 50 % erzielt. Der Energieverbrauch ist höher als bei der herkömmlichen Entfernung des Kopfes durch Abtrennen und Auswaschen der Eingeweide.

Anwendbarkeit

Anwendbar im Fischsektor, z. B. während des Zerlegens, Ausnehmens und Filetierens. Die Technik wurde bei der Heringsfiletierung eingesetzt, aufgrund des Energieverbrauchs und des Lärmpegels aber wieder aufgegeben.

Wirtschaftliche Aspekte

Einsparungen bei der Abwasserbehandlung. Da das Nebenprodukt einen geringeren Wassergehalt hat, kann es für einen höheren Preis verkauft werden.

Beispielanlagen

Wird in der Makrelenverarbeitung in den nordeuropäischen Ländern eingesetzt.

Referenzliteratur

[28, Nordic Council of Ministers, 1997, 134, AWARENET, 2002]

**4.7.2.6 Trockener Transport von Fett, Eingeweiden, Haut und Filets mittels feinmaschiger Förderbänder**Beschreibung

An Stelle von Transportwasser können beim Filetieren, Enthäuten und der Fett- und Eingeweideentfernung auch Förderbänder eingesetzt werden, und zwar entweder eins pro Maschine oder ein einzelnes feinmaschiges Förderband für alle Maschinen. Der trockene Transport wird mittels einer Rutsche durchgeführt, die eine Neigung von 20 % hat und unter dem Ausweidungsrads installiert wird. Eingeweide, fettes Bauchgewebe und das Wasser vom Rad werden von der Rutsche aufgefangen. Die Anwendung der Methode für eine Filetiermaschine wird in Abbildung 4.49 gezeigt. Von der Rutsche gleiten Eingeweidestreifen und Wasser auf ein feinmaschiges Förderband aus synthetischem Stoff, durch das das Wasser abläuft. Die Eingeweide werden in einen Behälter transportiert.

Beim Filetieren von Weißfisch wird der trockene Transport mit einem Filterförderband der Maschengröße 0,25 mm durchgeführt. Das Wasser aus den Maschinen und kleine Teilchen passieren den Filter, während Feststoffe wie Fett und Eingeweide zurückgehalten werden. Um die Vorrichtung sauberzuhalten und die Filterkapazität zu bewahren, kann es nötig sein, ein Wassersprühsystem zu installieren. Das Filtrat kann als Sprühwasser verwendet werden.

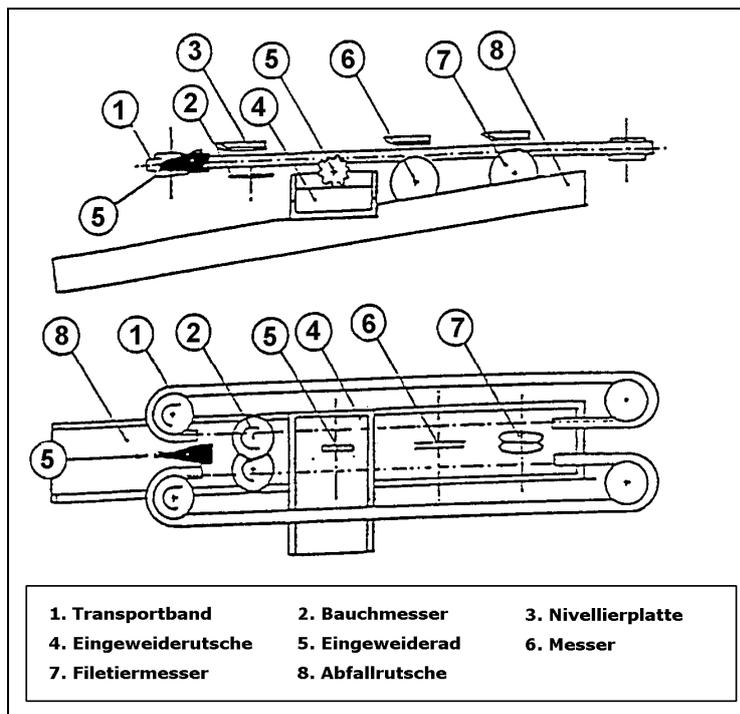


Abbildung 4.49: Anlage für die trockene Eingeweideentfernung

Erreichbare Umweltvorteile

Geringere Verschmutzung des Abwassers. Abfallminimierung; z. B. werden große Mengen an Nebenprodukten gesammelt, die für die Fischmehlproduktion verkauft werden können.

Medienübergreifende Auswirkungen

Wasserverbrauch, z. B. zur Kühlung von Messern und Rädern, zur Reinigung des Filterbandes und zum Ausspülen der Bauchhöhle. Es wird Energie verbraucht.

Betriebsdaten

Wie in Tabelle 4.83 angegeben, sinkt die Verschmutzungsfracht des Abwassers um 29 – 52 %.

| Parameter        | Nass<br>(kg/t roher Hering) | Trocken<br>(kg/t roher Hering) | Reduzierung<br>(%) |
|------------------|-----------------------------|--------------------------------|--------------------|
| Gesamtstickstoff | 1,4                         | 0,99                           | 30                 |
| Gesamtphosphor   | 0,17                        | 0,12                           | 29                 |
| CSB              | 26,3                        | 15,0                           | 43                 |
| Trockensubstanz  | 17,8                        | 10,9                           | 39                 |
| Öl               | 7,3                         | 3,5                            | 52                 |

Tabelle 4.83: Abwasserbelastung vor und nach der Einführung der trockenen Eingeweidebeseitigung

Feinmaschige Förderbänder unter Filetiermaschinen senken den gesamt CSB im abgegebenen Abwasser um etwa 5 – 15 %, wenn es sich um ein zentrales Förderband handelt, und um 15 – 25 %, wenn es sich um ein Trommelsieb handelt.

Anwendbarkeit

Anwendbar im Fischsektor, z. B. beim Häuten, Zerlegen, Ausnehmen und Filetieren.

Wirtschaftliche Aspekte

Einsparungen bei der Abwasserbehandlung. Da das Nebenprodukt einen geringeren Wassergehalt hat, kann es für einen höheren Preis verkauft werden.

Beispielanlagen

Wird in der dänischen Heringsindustrie (siehe Abschnitt 4.7.2.9.1), bei der Weißfischverarbeitung in den nordeuropäischen Ländern und in der Fischverarbeitungsindustrie im Vereinigten Königreich (siehe Abschnitt 4.7.2.9.2) eingesetzt.

Referenzliteratur

[28, Nordic Council of Ministers, 1997, 58, Envirowise (UK), 1999]

**4.7.2.7 Vermeidung des Entschuppens, wenn der Fisch anschließend noch enthäutet wird**Beschreibung

Entschuppungsgeräte bestehen aus einer perforierten rotierenden Trommel, aus der die Schuppen mit Wasser weggespült werden. Bei Fisch, der anschließend enthäutet wird, findet keine Entschuppung statt.

Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs. Geringerer Energieverbrauch.

Betriebsdaten

Es werden Wassereinsparungen von 10 – 15 m<sup>3</sup>/t erzielt.

Anwendbarkeit

Anwendbar im Fischsektor.

Referenzliteratur

[134, AWARENET, 2002]

**4.7.2.8 Verwendung des filtrierten, rückgeführten Abwassers vom Entschuppen für das Vorspülen von Fischen**Beschreibung

Entschuppungsgeräte bestehen aus einer perforierten rotierenden Trommel, aus der die Schuppen mit Wasser weggespült werden. Die Verwendung des filtrierten, rückgeführten Entschuppungsabwassers für das Vorspülen von Fischen minimiert den Gesamtwasserverbrauch. Auch der Entschuppungsvorgang wird durch Wiegen der Schuppenmenge für einen bestimmten Wasserdurchfluss entsprechend eingestellt.

Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs.

Betriebsdaten

Es werden Wassereinsparungen von bis zu 70 % angegeben.

Anwendbarkeit

Anwendbar im Fischsektor.

Referenzliteratur

[134, AWARENET, 2002]

**4.7.2.9 Fallstudien****4.7.2.9.1 Heringsverarbeitung in Dänemark**Beschreibung

Vor Anfang 1990 war die dänische Fischindustrie durch einen hohen Wasserverbrauch und die Abgabe großer Mengen organischer Substanzen ins Abwasser gekennzeichnet. Wie in Tabelle 4.84 angegeben, erzielte die Branche zwischen Anfang 1990 und 1997 mit dem Einsatz sauberer Techniken einen Rückgang des Wasserverbrauchs und der organischen Einleitung um 20 – 30 %.

| Verfahren  | Maßnahme  | Betroffener Bereich   |
|------------|---|---|
| Sortieren  | Austausch von Wasserdüsen (siehe Abschnitt 4.1.8.8)   | Wasserverbrauch   |
| Ausnehmen  | Trockenes Verfahren zur Entfernung und zum Abtransport von Fett und Eingeweiden (siehe Abschnitt 4.7.2.6) | Energie, organische und Nährstoffbelastung des Abwassers, Wiederverwendung von Abfällen |
| Filetieren | Bessere Verwendung, Beseitigung und/oder Austausch von Wasserdüsen (siehe Abschnitt 4.1.8.8)              | Wasserverbrauch   |
| Enthäuten  | Entfernung von Haut und Fett aus der Enthäutungstrommel mittels Vakuum (siehe Abschnitt 4.7.2.4)          | Wasserverbrauch, organische Belastung des Abwassers                                     |

**Tabelle 4.84: Techniken, die in Heringsindustrie eingesetzt werden, um Wasserverbrauch und Abwasserverschmutzung zu senken**

Des Weiteren wurden bei den an der Studie beteiligten Anlagen im Zeitraum von 1997 bis 2000 die Produktverfeinerung verbessert und die direkte Abgabe des Abwassers in Einleitungsgewässer durch einen Anschluss an die kommunale Kläranlage ersetzt. Im Jahr 2000 gaben nur noch drei der an der Studie teilnehmenden Unternehmen Abwasser separat in Einleitungsgewässer ab.

Die Ergebnisse früherer Projekte zur Einführung sauberer Techniken in diesem Sektor konnten beibehalten und in den meisten Fällen durch die Einführung von Umweltmanagementprogrammen (siehe Abschnitt 4.1.1) noch weiter verbessert werden. Einige Anlagen sind nach ISO 14001 zertifiziert, wogegen andere nicht-zertifizierte Umweltmanagementpläne angewandt haben. Zusätzlich wurden in allen Anlagen Umweltspezialisten, in einigen Fällen auch auf Führungsebene, eingestellt.

Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs. Geringerer Energieverbrauch. Geringere Verschmutzung des Abwassers. Abfallminimierung, z. B. durch Nutzung von Abfall als Nebenprodukt.

Betriebsdaten

Der Wasserverbrauch betrug 1989 etwa 2,5 bis 9 m<sup>3</sup>/t Rohstoff und die Verschmutzungsfracht des Wassers lag bei etwa 20 bis 120 kg CSB/t Rohstoff. Bis zum Jahr 2000 waren Wasserverbrauch und CSB-Frachten reduziert worden, und zwar auf etwa 1,3 bis 3,1 m<sup>3</sup>/t Rohstoff und 10 bis 24 kg CSB/t Rohstoff. Auch die früheren Schwankungen in der Umweltbilanz zwischen den Unternehmen sind erheblich reduziert worden. Der verbleibende Unterschied in den Umweltbilanzen lässt sich hauptsächlich auf die verschiedenen Stufen der Produktverfeinerung, den unterschiedlichen Einsatz von Vermeidungstechnologien und unterschiedliche Arten der Produktionsplanung zurückführen.

Obwohl die Ergebnisse der Umsetzung der obigen Maßnahmen in der Heringsproduktion positiv sind und der Umwelt insgesamt nutzen, ist auch klar, dass weiterhin nachsorgende Techniken erforderlich sind. Der Verschmutzungsgrad, z. B. als CSB oder Nährstoffgehalt angegeben, ist im unbehandelten Abwasser immer noch hoch, nämlich zwischen 2.000 und 10.000 mg CSB/l, 200 – 600 mg N/l und 40 – 100 mg P/l.

Beispielanlagen

Fünf Fischverarbeitungsanlagen in Dänemark.

Referenzliteratur

[147, Lehman N. and Nielsen E.H, 2002]

**4.7.2.9.2 Fischverarbeitung im Vereinigten Königreich**

Beschreibung

Ein Unternehmen für Fischprodukte (Nahrungsmittel) produziert jährlich 12.000 Tonnen tiefgekühlte und gekühlte Fischprodukte an zwei Standorten in Hull im Vereinigten Königreich. Die wichtigsten Produkte sind heiß geräucherte Makrele und Hering, kalt geräucherter Schellfisch, Weißfischfilets und paniertes und mit Teigmantel umhüllter Tiefkühlfisch.

Das Unternehmen führte 1996 ein Abfallminimierungsprojekt ein, das sich zunächst auf Wasser- und Abwasserfragen konzentrierte, aber bald auf Rohstoffe, Verpackungen und Energieverbrauch ausgeweitet wurde. Ein Abfallminimierungsteam untersuchte den Wasserverbrauch und die anfallende Abwassermenge für verschiedene Prozesse und erarbeitete Wasserbilanzen für die zwei Standorte des Unternehmens.

#### Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs. Verbesserte Energieeffizienz und Hygienestandards.

#### Betriebsdaten

Der Gesamtwasserverbrauch wurde um 58 % pro Tonne Produkt gesenkt. Die Maßnahmen zur Leistungsverbesserung umfassten u. a.:

- Einsatz neuer Auftaugeräte zur Eliminierung von Wasserverlusten durch Leckagen
- Verbesserung der Reinigungsverfahren, z. B. Reduzierung der Schlauchanzahl und Aufforderung an das Personal, Fischabfälle mit Kunststoffschaufeln und Gummiabziehern aufzusammeln (siehe Abschnitt 4.3.1)
- Einsatz von trockenen Filetverfahren (siehe Abschnitt 4.7.2.6)
- Reparatur sämtlicher Lecks (siehe Abschnitt 4.1.5)
- Schulung und Förderung des Bewusstseins der Mitarbeiter (siehe Abschnitt 4.1.2).

#### Wirtschaftliche Aspekte

Das Projekt zur Wasserverbrauchs- und Abwasserminimierung erbrachte u. a. folgenden Nutzen:

- Kosteneinsparungen von mehr als 150.000 EUR/Jahr,
- Amortisationsdauer von 36 Wochen für die neue Auftauvorrichtung.

#### Anlass für die Umsetzung

Das Unternehmen erfuhr im November 1996, dass seine Abwassergebühren im Januar 2001 erheblich ansteigen würden.

#### Beispielanlagen

Ein Fischverarbeitungsbetrieb in Hull, Vereinigtes Königreich.

#### Referenzliteratur

[58, Envirowise (UK), 1999]

### **4.7.3 Obst und Gemüse**

#### **4.7.3.1 Trennung der anfallenden Stoffe zur Optimierung von Verbrauch, Wiederverwendung, Rückgewinnung, Wiederverwertung und Entsorgung (sowie zur Minimierung von Wasserverbrauch und Abwasserunreinigung)**

Diese Technik wird in Abschnitt 4.1.7.6 beschrieben.

#### Dokumentierte Beispiele für die Anwendung der Technik

Es gibt wahrscheinlich noch zahlreiche andere Möglichkeiten, wie diese Technik innerhalb des Sektors eingesetzt werden kann.

- Entfernung von feinem organischem Material, wenn z. B. Kartoffeln in die Anlage gebracht werden
- Verringerung von Sortier-, Verschüttungs- und Spritzverlusten durch Einbau von Auffangschalen, Klappen und Sieben
- Einsatz trockener Abscheidung und trockener Sammlung von Feststoffen, halbfesten Rückständen und verworfenen Rohstoffen, z. B. beim Sortieren, Putzen, Extrahieren und Filtrieren.
- Abscheidung fester organischer Stoffe aus dem Abwasser des Schälprozesses, z. B. mittels Sieben, Filtern und Zentrifugation, um das Versickern einzuschränken.
- Einbau von Klappen und Sieben an Förderbändern.

#### Anwendbarkeit

Anwendbar in allen Anlagen, die Obst und Gemüse verarbeiten.

### Referenzliteratur

[31, VITO, et al., 2001]

#### **4.7.3.2 Trockenreinigung**

Diese Technik wird in Abschnitt 4.3.1 beschrieben.

#### Dokumentiertes Beispiel für die Anwendung der Technik

Es gibt wahrscheinlich noch zahlreiche andere Möglichkeiten, wie diese Technik innerhalb des Sektors eingesetzt werden kann.

- verschüttetes Gemüse soweit wie möglich von Hand beseitigen und das Wegspülen mit Wasser vermeiden.

#### Anwendbarkeit

Anwendbar in allen Anlagen, die Obst und Gemüse verarbeiten.

### Referenzliteratur

[31, VITO, et al., 2001]

#### **4.7.3.3 Geschützte Freiluftlagerung von Obst und Gemüse**

##### Beschreibung

Abfall wird minimiert, wenn Obst, Gemüse und organische Abfälle wie Schalen und Schnittabfall in einem sauberen Hof im Schatten und vor Regen geschützt oder vollständig abgeschlossen in Behältern gelagert werden. So wird die Kontamination minimiert, und die Nahrungsmittelstoffe sind vor Schäden durch nasses Wetter geschützt.

##### Erreichbare Umweltvorteile

Weniger Abfall.

##### Medienübergreifende Auswirkungen

Durch die Lagerung im Freien können Insekten, Vögel und Nagetiere angelockt werden.

##### Betriebsdaten

Manche Obst- und Gemüsesorten können durch zu hohe oder zu niedrige Umgebungstemperaturen geschädigt werden.

##### Anwendbarkeit

Anwendbar in allen Anlagen, in denen Rohstoffe und Erzeugnisse gelagert werden müssen.

##### Anlass für die Umsetzung

Vollständige Nutzung des Produkts und weniger Abfall.

### Referenzliteratur

[31, VITO, et al., 2001]

#### **4.7.3.4 Schälen von Obst und Gemüse**

Das Schälen wird in den Abschnitten 2.1.1.3 bis 2.1.1.3.3 beschrieben. Ziel des Schälen ist es, die Haut/Schale von rohem Obst und Gemüse zu entfernen und dabei so wenig wie möglich des darunter befindlichen Nahrungsmittels zu beseitigen, gleichzeitig aber eine saubere Schäloberfläche zu erzielen. Das Schälen wird im Industriemaßstab bei Obst und Gemüse angewendet. Es gibt verschiedene Schälmethode, die in den folgenden Abschnitten (4.7.3.4.1 bis 4.7.3.4.7) beschrieben werden. Die Beseitigung unerwünschten oder ungenießbaren Materials von rohem Obst und Gemüse, z. B. von Lauch und Artischocken, wird als Putzen bezeichnet (siehe Abschnitt 2.1.1.2). Angaben zufolge kann das Reinigungswasser von Dosen und Gläsern zum Schälen wiederverwendet werden.

#### 4.7.3.4.1 Dampfschälung – kontinuierlicher Prozess

##### Beschreibung

Der kontinuierlich arbeitende Dampfschäler ist eine Trommel, in der sich eine Schraube befindet. Der Dampf wird direkt in die Trommel eingeleitet, meist mit geringerem Druck als im Chargenbetrieb (siehe Abschnitt 4.7.3.4.2), und das Produkt wird während einer einstellbaren Verweilzeit erwärmt. Der größte Teil des Schälmaterials wird mit dem Dampf abgegeben. Verbleibende Spuren werden mit Wasser abgespritzt. Dieses Wasser kann gefiltert und zum Waschen von rohem Obst und Gemüse wieder verwendet werden.

Wenn zum Entfernen der Schale ein trockener Abbürstvorgang mit einem Bürstenfördersystem anstatt Wasser verwendet wird, kommt es den Angaben zufolge zu einer schwerwiegenden bakteriellen Kontamination der Bürsten und damit unvermeidlich zur Schädigung des Obst- oder Gemüsegewebes.

##### Erreichbare Umweltvorteile

Weniger Abfallerzeugung als bei anderen Schältechniken, und die Schale wird oft rückgewonnen und als Tierfutter verwendet. Verbraucht weniger Wasser als eine Kombination aus Abrieb- und Messerschälung.

##### Medienübergreifende Auswirkungen

Erhöhter Dampfverbrauch im Vergleich zur nassen oder trockenen Laugenschälung. Hoher Wasserverbrauch und starke Abwasserkontamination. Es kann zu Geruchsproblemen kommen.

##### Betriebsdaten

Bei der Dampfschälung wird etwa fünfmal so viel Dampf, z. B. als Energiequelle, verbraucht wie bei der Laugenschälung.

In Tabelle 4.85 sind Energieträger und Verbrauch bei der Dampfschälung vor dem Einfrieren von Gemüsen angegeben.

| Energieträger                     | Ungefährer Verbrauch |
|-----------------------------------|----------------------|
| Heißwasser (kWh/t Tiefkühlgemüse) | 0                    |
| Dampf (t/t Tiefkühlgemüse)        | 0,9                  |
| Dampfdruck (bar)                  | 7 – 15               |
| Strom (kWh/t Tiefkühlgemüse)      | 3,5                  |

**Tabelle 4.85: Energieträger und Verbrauch bei der Dampfschälung vor dem Einfrieren von Gemüsen**

Bei der Dampfschälung werden große Wassermengen verbraucht, bis zu fünf Mal mehr als bei der Laugenschälung, jedoch nur halb soviel wie bei der Kombination aus Abrieb- und Messerschälung. Außerdem fällt Abwasser mit großen Mengen von Produktrückständen an. In Kartoffelverarbeitungsanlagen können die Schalen bis zu 80 % des gesamten BSB verursachen. Bei der Obstverarbeitung kann das Schälabwasser bis zu 10 % des gesamten Abwasserstroms und 60 % des BSB darstellen. Wenn Dampfschälung benutzt wird, kann der Dampf mit kaltem Wasser kondensiert werden. Wird keine Wasserkühlung verwendet, wird weniger Wasser verbraucht, weniger Abfall produziert und das Abwasser trägt geringere organische Frachten. Der Produktverlust beim Schälprozess beträgt 8 – 15 %.

Der Abfall besteht aus festen Schalenrückständen sowie aus gelösten Substanzen wie Stärke und Gewebeflüssigkeiten. Das feste Material wird im Allgemeinen durch Sedimentation abgeschieden, getrocknet und kompostiert. Diese Fraktion enthält Mineralien und bioaktive phenolische Substanzen, aber im Fall von Kartoffeln auch Glykoalkaloide, sodass der direkte Einsatz als Nährstoff eingeschränkt ist.

In Abbildung 4.50 ist der Dampfschälprozess in einer Beispielanlage dargestellt. Im Vergleich dazu (siehe Abbildung 4.51) ist die Abgabe von Substanzen bei Abriebschälung und anschließender Messerschälung gezeigt.

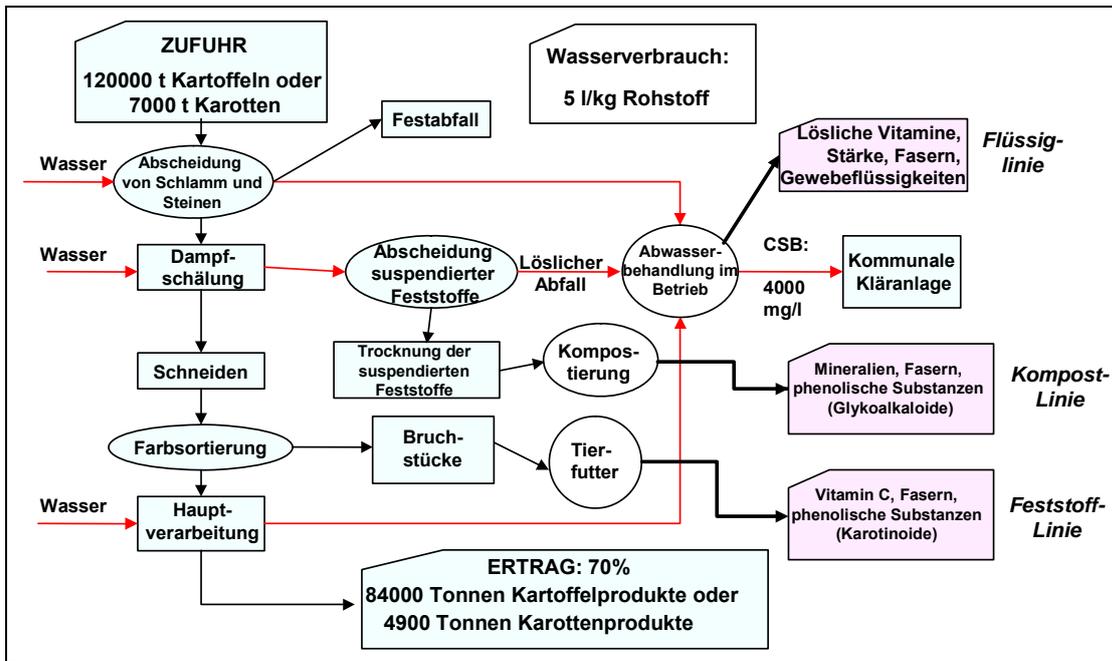


Abbildung 4.50: Dampfschälprozess in einer Beispielanlage in Finnland

Anwendbarkeit

Anwendbar bei Obst und Gemüse, das geschält werden muss, mit Ausnahme von Sorten, bei denen die Schale viel härter als das Fruchtfleisch ist (sofern keine Weiterverarbeitung zu gekochtem Obst oder Saft erfolgt).

Wirtschaftliche Aspekte

Die Dampfschälung ist den Angaben zufolge wirtschaftlicher als die Abrieb-, Messer- oder Laugenschälung.

Beispielanlagen

Weit verbreitet für das Schälen großer Mengen von Kartoffeln, Süßkartoffeln, Schwarzwurzeln, Rüben, Karotten und anderen Knollengemüsen sowie Tomaten.

Referenzliteratur

[31, VITO, et al., 2001, 32, Van Bael J., 1998, 134, AWARENET, 2002, 182, Germany, 2003]

**4.7.3.4.2 Dampfschälung – Chargenbetrieb**

Beschreibung

Die Dampfschälung kann auch chargenweise erfolgen. Die Rohstoffe, z. B. Wurzeln und Knollen, werden in einem sich drehenden Druckgefäß dem Dampf mit hohem Druck (1.500 bis 2.000 kPa) ausgesetzt. Durch die hohe Temperatur kommt es zu einer schnellen Erwärmung und dem Garen der Oberflächenschicht innerhalb von 15 bis 30 Sekunden. Der Druck wird dann plötzlich abgelassen, wodurch die gekochte Schale sich blitzschnell ablöst. Der größte Teil des abgeschälten Materials wird mit dem Dampf abgegeben und führt zu einem konzentrierten Abfallstrom. Wasser wird zusätzlich nur zur Beseitigung etwaiger Spuren gebraucht.

Wenn zum Entfernen der Schale ein trockener Abbürstvorgang mit einem Bürstenfördersystem anstatt Wasser verwendet wird, kommt es den Angaben zufolge zu einer schwerwiegenden bakteriellen Kontamination der Bürsten und damit unvermeidlich zur Schädigung des Obst- oder Gemüsegewebes.

Erreichbare Umweltvorteile

Weniger Wasserverbrauch und Abwassererzeugung im Vergleich zur kontinuierlichen Dampfschälung, aber größere Mengen an Produktrückständen. Weniger Abfallerzeugung als bei anderen Schältechniken, und die Schale wird oft rückgewonnen und als Tierfutter verwendet. Geringere Abwasserfracht im Vergleich zur Abriebschälung mit anschließender Messerschälung.

Medienübergreifende Auswirkungen

Höherer Energieverbrauch als bei der Laugenschälung. Es kann zu Geruchsproblemen kommen.

Betriebsdaten

In Tabelle 4.85 sind Energieträger und Verbrauch bei der Dampfschälung angegeben.

Wasserverbrauch und Abwassermenge sind geringer als bei der kontinuierlichen Dampfschälung. Bei Tomaten reicht der verwendete Druck von 200 kPa bis 350 kPa. Diese Schälmethode wird den Angaben zufolge immer beliebter, was auf den geringeren Wasserverbrauch, die minimalen Produktverluste, das gute Erscheinungsbild der Schäloberflächen und die möglichen hohen Durchsätze von bis zu 4.500 kg/h bei automatischer Steuerung des Schälzyklus zurückzuführen ist.

Der Abfall besteht aus festen Schalenrückständen sowie aus gelösten Substanzen wie Stärke und Gewebeflüssigkeiten. Das feste Material wird im Allgemeinen durch Sedimentation abgetrennt, getrocknet und kompostiert. Diese Fraktion enthält Mineralien und bioaktive phenolische Substanzen, aber im Fall von Kartoffeln auch Glykoalkaloide, sodass der direkte Einsatz als Nährstoff eingeschränkt ist.

Anwendbarkeit

Anwendbar bei Obst und Gemüse, das geschält werden muss, mit Ausnahme von Sorten, bei denen die Schale härter ist als das Fruchtfleisch (sofern keine Weiterverarbeitung zu gekochtem Obst oder Saft erfolgt).

Wirtschaftliche Aspekte

Die Dampfschälung ist den Angaben zufolge wirtschaftlicher als die Abrieb-, Messer- oder Laugenschälung.

Beispielanlagen

Weit verbreitet für das Schälen großer Mengen von Kartoffeln, Süßkartoffeln, Schwarzwurzeln, Rüben, Karotten und anderen Knollengemüsen sowie Tomaten.

Referenzliteratur

[31, VITO, et al., 2001, 32, Van Bael J., 1998, 134, AWARENET, 2002, 182, Germany, 2003]

**4.7.3.4.3 Abriebschälung**Beschreibung

Bei der Abriebschälung wird das zu schälende Material entweder auf Karborundumrollen oder in eine sich drehende und mit Karborundum ausgekleidete Schüssel gegeben. Die raue Oberfläche des Karborundums entfernt die Haut, die dann mit reichlich Wasser weggespült wird. Das Verfahren läuft normalerweise bei Umgebungstemperatur ab.

Erreichbare Umweltvorteile

Die Schale kann rückgewonnen und als Tierfutter verwendet werden. Geringerer Energieverbrauch.

Medienübergreifende Auswirkungen

Es werden große Mengen an Wasser verbraucht. Es gibt große Produktverluste und es fällt sehr viel Abwasser an. Es kann zu Geruchsproblemen kommen. Die Kombination aus Abriebschälung und Messerschälung führt zu einer stärkeren Verschmutzung des Abwassers als die Dampfschälung.

Betriebsdaten

Diese Technik geht mit erheblich größeren Produktverlusten (25 %) einher als die Dampfschälung (8 – 15 %). Wenn das Gemüse nach Größe sortiert ist und ähnliche Größen gleichzeitig geschält werden, lässt sich der Anteil des beim Schälen entfernten Fruchtfleischs verringern. Es wird ebenfalls erheblich mehr Abwasser produziert als bei der Dampfschälung. Dieses verdünnte Abwasser enthält den großen Produktverlust und seine Behandlung ist teuer und kompliziert.

Es wird keine Energie zur Erwärmung von Wasser oder zur Dampferzeugung benötigt, aber für den Betrieb der Rollen bzw. des rotierenden Kessels.

Der relativ geringe Durchsatz ist darauf zurückzuführen, dass alle Nahrungsmittelstücke mit den rauen Oberflächen in Berührung kommen müssen. Es kann Probleme mit der Hygiene geben, da durch den Wegfall des Schälwassers auch dessen Kühleffekt ausbleibt und es örtlich zu hohen Temperaturen kommen kann. Dennoch kann Angaben zufolge die Kartoffelqualität beim Schälen mit Karborundum erhalten bleiben.

### Anwendbarkeit

Die Technik wird zum Schälen von Zwiebeln, Kartoffeln, Karotten und Rüben eingesetzt, da hier die Haut leicht entfernbar ist und die Produktqualität gewahrt bleiben kann. Manchmal wird die Abribschälung als Vorschälsschritt vor der Messerschälung eingesetzt (siehe Tabelle 4.86).

### Wirtschaftliche Aspekte

Investitions- und Energiekosten sind gering. Die Dampfschälung gilt als wirtschaftlicher.

### Beispielanlagen

Weit verbreitet für das Schälen von Kartoffeln und Zwiebeln.

### Referenzliteratur

[1, CIAA, 2002, 31, VITO, et al., 2001, 182, Germany, 2003, 200, CIAA, 2003, 208, CIAA-AAC-UFE, 2003, 232, Fellows P J, ]

#### **4.7.3.4.4 Messerschälung**

### Beschreibung

Bei der Messerschälung wird das Schälgut gegen rotierende Klingen gedrückt oder entlang stationärer Klingen rotiert. Obwohl während des eigentlichen Schälvorgangs kein Wasser verbraucht wird, werden Rollen und Klingen fortlaufend gereinigt, sodass kontaminiertes Abwasser anfällt.

### Erreichbare Umweltvorteile

Die Schale kann rückgewonnen und direkt als Tierfutter oder zur Rückgewinnung ihrer Bestandteile genutzt werden. Geringerer Energieverbrauch als bei der Dampfschälung.

### Medienübergreifende Auswirkungen

Geruchsemissionen und Lärmverschmutzung. Die Kombination aus Abribschälung und Messerschälung führt zu einer stärkeren Verschmutzung des Abwassers als Dampfschälung und zur Verdoppelung des Wasserverbrauchs.

### Betriebsdaten

Der Produktverlust nach der Messerschälung beträgt 16 – 17 %. Durch Scharfhalten der Messer werden Produktschäden und damit Abfallmengen gemindert. Nach dem Schneiden werden fehlerhafte Stücke, die z. B. zu dunkel oder zu klein sind, aussortiert und als Tierfutter verwendet. Bei der Karottenverarbeitung können mehrere wertvolle Stoffe wie Vitamin C, Ballaststoffe, Phenolverbindungen und Karotinoide als Nebenprodukte rückgewonnen werden.

Tabelle 4.86 zeigt die Auswirkung einer Kombination aus Vorschälen mit Karborundum und anschließender Messerschälung auf die Wasserverschmutzung bei der Herstellung von halben Birnen in Sirup.

|   | <b>BSB (kg/t)</b> | <b>CSB (kg/t)</b> | <b>Suspendierte Feststoffe (kg/t)</b> |
|---|-------------------|-------------------|---------------------------------------|
| Karborundum-Vorschälen plus Messerschälung  | 21,6              | 36,5              | 21,5                                  |
| Wasserverbrauch, wenn das Wasser nach dem Sterilisieren nicht zur Kühlung der Dosen wiederverwendet wird 29,6 m <sup>3</sup> /t.<br>Wasserverbrauch, wenn das Wasser nach dem Sterilisieren zur Kühlung der Dosen wiederverwendet wird 6,2 m <sup>3</sup> /t. |                   |                   |                                       |

**Tabelle 4.86: Auswirkung einer Kombination aus Vorschälen mit Karborundum und anschließender Messerschälung auf die Wasserverschmutzung bei der Herstellung von halben Birnen in Sirup**

Abbildung 4.51 zeigt ein Flussdiagramm der Kartoffel- und Karottenverarbeitung mit den abgegebenen Stoffen, wenn Abribschälung mit nachfolgender Messerschälung eingesetzt werden. Die Abgaben können mit der in Abbildung 4.50 dargestellten Dampfschälung verglichen werden.

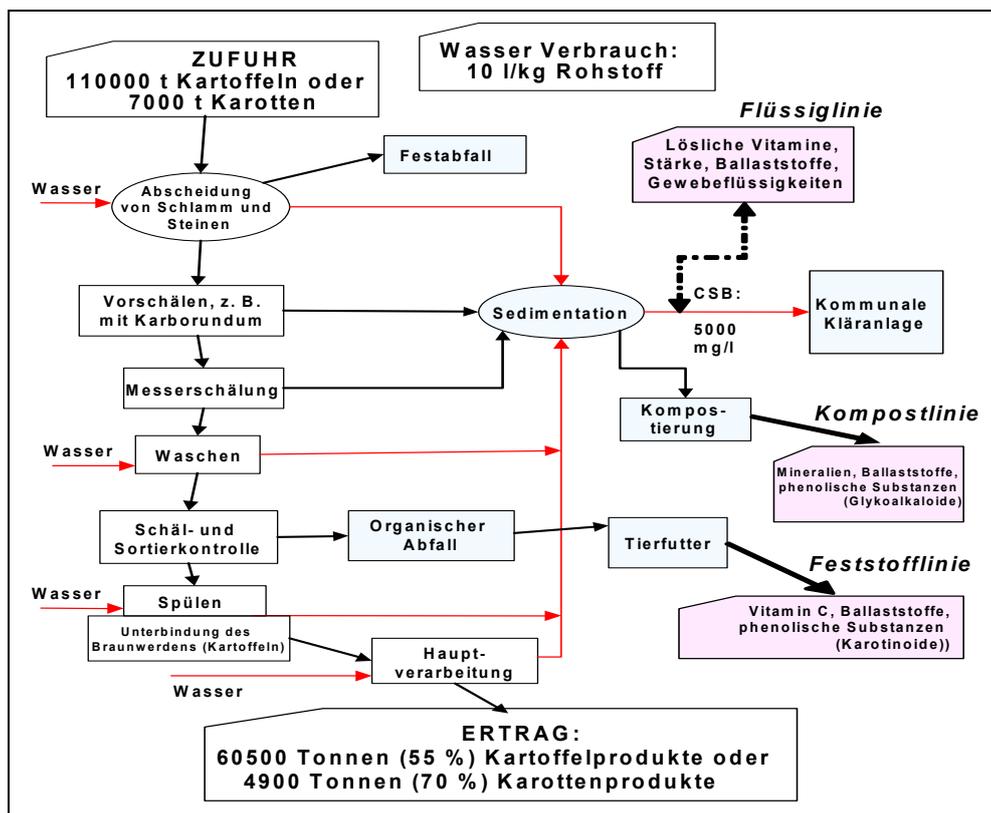


Abbildung 4.51: Flussdiagramm der Kartoffel- und Karottenverarbeitung in einer finnischen Anlage

#### Anwendbarkeit

Messerschälung wird insbesondere bei Zitrusfrüchten eingesetzt, bei denen sich die Schale leicht entfernen lässt und die Frucht kaum beschädigt wird, sowie für kleine Mengen von beispielsweise Kartoffeln, Karotten, Rüben und Äpfeln, oder wenn Gemüse von Gaststätten oder in Großküchen verwendet wird. Pfirsiche und Birnen können mit sehr kleinen, auf Rollen montierten Klingen geschält werden.

#### Wirtschaftliche Aspekte

Messerschälung ist den Angaben zufolge teurer als Dampfschälung.

#### Referenzliteratur

[1, CIAA, 2002, 31, VITO, et al., 2001, 124, Italy, 2002, 134, AWARENET, 2002, 182, Germany, 2003, 200, CIAA, 2003, 208, CIAA-AAC-UFE, 2003]

#### 4.7.3.4.5 Nasse Laugenschälung

##### Beschreibung

Das zu schälende Gut wird entweder in eine verdünnte Natronlauge mit einer Konzentration von 1 – 2 % oder auch bis zu 20 % gegeben oder durch diese geführt. Dabei hat die Lauge eine Temperatur von 80 – 120 °C. Dadurch wird die Schale weich und kann dann mit unter hohem Druck stehendem Wasser abgespritzt werden. Die Laugenkonzentration und die Temperatur richten sich nach der Art des behandelten Obstes oder Gemüses und nach dem erforderlichen Schälgrad. Obwohl während des eigentlichen Schälvorgangs kein Wasser verbraucht wird, wird Wasser für die fortlaufende Reinigung von Rollen und Klingen gebraucht, sodass kontaminiertes Abwasser anfällt.

##### Erreichbare Umweltvorteile

Weniger Wasser- und Energieverbrauch im Vergleich zur Dampfschälung.

##### Medienübergreifende Auswirkungen

Es entsteht Abwasser mit hohem pH-Wert und starker organischer Fracht. Es wird stark alkalischer oder salziger Festabfall produziert, der schwer zu entsorgen ist. Durch den Einsatz der Chemikalien kann die weitere Verwendung der in den Schalen enthaltenen Nährstoffe eingeschränkt sein. Wenn die Schale aufgrund ihres

Nährstoffgehalts genutzt wird, muss eine getrennte Abwasserbehandlung erfolgen. Es kommt zu Geruchsemissionen und Lärmverschmutzung. Das Produkt kann an Farbe verlieren.

Betriebsdaten

Durch den Einsatz der Laugenschälung kann es zu pH-Schwankungen im Abwasser kommen. Außerdem führt die Laugenschälung zu einer stärkeren Lösung von Stoffen und damit zu höherem CSB-, BSB-Gehalten und größeren Frachten suspendierter Feststoffe. BSB- und CSB-Konzentrationen sind höher als nach Abriebschälung mit anschließender Messerschälung, aber der Gehalt an suspendierten Feststoffen ist geringer. Bei Laugenschälung wird weniger Energie verbraucht, sowohl in elektrischer als auch in Dampfform, als bei der Dampfschälung, aber es entstehen höhere Frachten für die Kläranlage. Bei der nassen Laugenschälung wird viermal weniger Wasser verbraucht als bei der Dampfschälung. Manche Produkte wie Tomaten erfordern starke Laugen und die Zugabe von Benetzungsmitteln. Bei sauren Gurken beträgt die Laugenkonzentration ungefähr 2 %, bei Karotten etwa 10 % und bei Kürbissen bis zu 20 %. Der Produktverlust liegt bei 17 %.

Tabelle 4.87 zeigt die Auswirkung der Laugenschälung auf die Wasserverschmutzung bei der Herstellung von halben Birnen in Sirup. Die Zahlen können verglichen werden mit Tabelle 4.86, in der die entsprechenden Angaben für die Abriebschälung mit anschließender Messerschälung angegeben sind. Tabelle 4.88 gibt Energieträger und Verbrauch bei der Laugenschälung vor dem Einfrieren von Gemüse an.

|   | BSB (kg/t) | CSB (kg/t) | Suspendierte Feststoffe (kg/t) |
|---|------------|------------|--------------------------------|
| Laugenschälung  | 39,7       | 66,3       | 11,4                           |
| Wasserverbrauch, wenn das Wasser nach dem Sterilisieren nicht zur Kühlung der Dosen wiederverwendet wird 29,6 m³/t. |            |            |                                |
| Wasserverbrauch, wenn das Wasser nach dem Sterilisieren zur Kühlung der Dosen wiederverwendet wird 6,2 m³/t.        |            |            |                                |

**Tabelle 4.87: Auswirkung der Laugenschälung auf die Wasserverschmutzung bei der Herstellung von halben Birnen in Sirup**

| Energieträger                     | Ungefährer Verbrauch |
|-----------------------------------|----------------------|
| Heißwasser (kWh/t Tiefkühlgemüse) | 0                    |
| Dampf (t/t Tiefkühlgemüse)        | 0,16                 |
| Dampfdruck (bar)                  | 7                    |
| Strom (kWh/t Tiefkühlgemüse)      | 2                    |

**Tabelle 4.88: Energieträger und Verbrauch bei der Laugenschälung vor dem Einfrieren von Gemüse**

In einer Beispielanlage wurden Wasserverbrauch und die anfallende Abwassermenge für die nasse und trockene Laugenschälung (siehe Abschnitt 4.7.3.4.6) an einem Standort verglichen, an dem täglich 72 Tonnen rote Beete verarbeitet werden. Bei gleicher Menge an verarbeitetem Produkt wurde durch die trockene Laugenschälung im Vergleich zur nassen Laugenschälung der Wasserverbrauch um 75 % gesenkt und der Festabfall um 90 %. Außerdem enthielt das bei der trockenen Laugenschälung anfallende Abwasser 88 % weniger suspendierte Feststoffe und hatte einen um 94 % geringeren CSB und einen um 93 % geringeren BSB als das Abwasser aus der nassen Laugenschälung. Aber die mit Lauge kontaminierte Schale wird Berichten zufolge zumindest in einigen Fällen nach einer Pufferung in die Kläranlage entsorgt. Bei der trockenen Laugenschälung wird tendenziell weniger Lauge verbraucht als bei den nassen Verfahren.

Anwendbarkeit

Anwendbar auf sämtliches Schälobst und -gemüse. Kann eingesetzt werden, wenn die Schale im Vergleich zum Fruchtfleisch relativ hart ist und die Dampfschälung nicht geeignet ist.

Wirtschaftliche Aspekte

Bei der nassen Laugenschälung entsteht Abwasser mit sehr hohem pH-Wert und starker organischer Fracht, das die Wasserbehandlungskosten in die Höhe treibt. Laugenschälung ist den Angaben zufolge teurer als Dampfschälung.

Beispielanlagen

Wird zum Schälen von Kartoffeln, Karotten, Rüben, Schwarzwurzeln, Pfirsichen, Aprikosen, Äpfeln, Birnen, Tomaten, Paprika, Kürbissen, Gurken und Zitrusfrüchten eingesetzt. Den Angaben zufolge wird die Technik

zum Schälen von Äpfeln benutzt, weil bei der Dampfschälung (siehe Abschnitt 4.7.3.4.1) das Fruchtfleisch beschädigt wird.

#### Referenzliteratur

[1, CIAA, 2002, 13, Environment Agency of England and Wales, 2000, 31, VITO, et al., 2001, 32, Van Bael J., 1998, 45, Envirowise (UK) and Ashact, 2001, 124, Italy, 2002, 182, Germany, 2003, 200, CIAA, 2003, 208, CIAA-AAC-UFE, 2003]

#### **4.7.3.4.6 Trockene Laugenschälung**

##### Beschreibung

Bei der trockenen Laugenschälung wird das Material in eine auf 80 – 120 °C heiße Lauge mit einer Konzentration von 10 % eingetaucht, um die Schale zu weich zu machen, die anschließend mit Gummischieben oder -rollen entfernt wird. Dadurch sinkt der Wasserverbrauch und es fällt eine konzentrierte alkalische Paste zur Entsorgung an. Nach dem Schälen folgt ein Waschvorgang zur Entfernung der Schale und von Laugenrückständen.

Beim Schälen von Pfirsichen und Aprikosen ist die Schale sehr fein und weich und lässt sich nicht so leicht vom Fruchtfleisch unterscheiden wie z. B. bei Tomaten, Paprika und Kartoffeln; sie „klebt“ am Fleisch. Dieses Kleben ist bei weniger reifen Früchten stärker ausgeprägt als bei reiferen. Pfirsiche und Aprikosen werden in die Laugenlösung eingetaucht, und die Schale zersetzt sich. Rückstände werden durch Abspritzen des Obstes mit Wasser entfernt. In der Praxis werden Früchte unterschiedlichen Reifegrades gemeinsam geschält; dabei wird so lange gewartet, bis auch die unreifsten Früchte abgeschält sind. Beim Schälen von z. B. Pfirsichen und Aprikosen für die nachfolgende Konservierung in ganzen oder halben Früchten würde die mechanische Entfernung der aufgeweichten Schale einen nicht akzeptablen Schaden an der Fruchtoberfläche bedeuten.

##### Erreichbare Umweltvorteile

Weniger Wasserverbrauch als bei der Dampfschälung und bei der nassen Laugenschälung. Weniger Festabfall und Abwasser als bei der nassen Laugenschälung. Geringerer Laugenverbrauch als bei der nassen Laugenschälung. Weniger Energieverbrauch im Vergleich zur Dampfschälung.

##### Medienübergreifende Auswirkungen

Es fällt stark alkalischer oder sehr salziger Festabfall an. Durch den Chemikalieneinsatz kann die Nutzung der Nährstoffe aus der abgeschiedenen Schalenmasse eingeschränkt sein. Es entsteht Geruch. Es kann zu Lärmproblemen kommen. Das Produkt kann an Farbe verlieren.

##### Betriebsdaten

Mit trockenen Laugenschälverfahren lassen sich Volumen und Belastung des Abwassers im Vergleich zu Dampfschälung und nasser Laugenschälung deutlich verringern. Die Schalen können als pumpbare Schlämme aufgefangen werden, die entsorgt werden müssen. Die mit Lauge kontaminierte Schale wird Berichten zufolge zumindest in einigen Fällen nach einer Pufferung in die Kläranlage entsorgt. Bei der trockenen Laugenschälung wird tendenziell weniger Lauge verbraucht als bei der nassen Laugenschälung (siehe Abschnitt 4.7.3.4.5).

In einer Beispielanlage wurden Wasserverbrauch und die anfallende Abwassermenge für die nasse und trockene Laugenschälung an einem Standort verglichen, an dem täglich 72 Tonnen rote Beete verarbeitet werden. Bei gleicher Menge an verarbeitetem Produkt wurde durch die trockene Laugenschälung im Vergleich zur nassen Laugenschälung der Wasserverbrauch um 75 % gesenkt und der Festabfall um 90 %. Außerdem enthielt das bei der trockenen Laugenschälung anfallende Abwasser 88 % weniger suspendierte Feststoffe und hatte einen um 94 % geringeren CSB und einen um 93 % geringeren BSB als das Abwasser aus der nassen Laugenschälung.

##### Anwendbarkeit

Anwendbar bei Schälobst und -gemüse. Kann eingesetzt werden, wenn die Schale im Vergleich zum Fruchtfleisch relativ hart und die Dampfschälung nicht geeignet ist.

##### Wirtschaftliche Aspekte

Bei der trockenen Laugenschälung entsteht Abwasser mit sehr hohem pH-Wert, das die Wasserbehandlungskosten in die Höhe treibt. Trockene Laugenschälung ist den Angaben zufolge teurer als Dampfschälung.

### Beispielanlagen

Wird für das Schälen von Kartoffeln, Karotten, Schwarzwurzeln, Äpfeln, Pfirsichen und Aprikosen eingesetzt.

### Referenzliteratur

[1, CIAA, 2002, 31, VITO, et al., 2001, 32, Van Bael J., 1998, 45, Envirowise (UK) and Ashact, 2001, 124, Italy, 2002, 182, Germany, 2003, 208, CIAA-AAC-UFE, 2003, 258, Federación Nacional de Asociaciones de la Industria de Conservas Vegetales, 2005]

#### 4.7.3.4.7 Flammenschälung

##### Beschreibung

Diese Technik wurde für Zwiebeln entwickelt. Ein Flammenschäler besteht aus einem Förderband, das das Schälgut in Rotationsbewegung durch einen Ofen transportiert, der auf Temperaturen oberhalb von 1.000 °C geheizt wird. Haut und Wurzelhaare werden abgebrannt und mit Hochdruckwasserspritzen entfernt.

##### Erreichbare Umweltvorteile

Flammenschälung erfordert Wärme im Gegensatz zu anderen Schälverfahren, die elektrische Energie benötigen.

##### Medienübergreifende Auswirkungen

Bei der Flammenschälung kommt es zu Staub- und Geruchsemissionen.

##### Betriebsdaten

Der durchschnittliche Produktverlust beträgt 9 %. Angaben zufolge ist für die roten Paprikaschoten, die für das spanische Rezept „Piquillo-Paprika“ gebraucht werden, Flammenschälung unerlässlich.

##### Anwendbarkeit

Flammenschälung wird bei Zwiebeln und Paprika angewandt.

##### Referenzliteratur

[134, AWARENET, 2002]

#### 4.7.3.5 Blanchieren von Obst und Gemüse

Das Blanchieren wird in Abschnitt 2.1.5.2 beschrieben. Es besteht im Allgemeinen aus drei Schritten, nämlich dem Vorwärmen, dem Blanchieren und dem Abkühlen. Im Anschluss finden weitere Verarbeitungsschritte wie die Konservenherstellung oder das Tiefkühlen statt. Tabelle 4.89 zeigt einen qualitativen Vergleich des Energie- und Wasserverbrauchs bei den verschiedenen Blanchiertechniken.

| Blanchiertechnik                                 | Energie | Wasser |
|--|---------|--------|
| Dampfblanchieren mit Luftkühlung                 | 3       | 1      |
| Förderbandblanchieren mit Wasserkühlung          | 1       | 3      |
| Förderbandblanchieren mit Luftkühlung            | 4       | 2      |
| Trommelblanchieren mit Gegenstrom-Wasserkühlung  | 2       | 4      |
| 1: Geringster Verbrauch<br>4: Höchster Verbrauch |         |        |

Tabelle 4.89: Vergleich des Energie- und Wasserverbrauchs bei den verschiedenen Blanchiertechniken

##### 4.7.3.5.1 Dampfblanchieren mit Luftkühlung

###### Beschreibung

Das Dampfblanchieren ist ein kontinuierlicher Prozess, bei dem das Nahrungsmittel auf einem langen perforierten Förderband bewegt wird. Während des Vorwärmens wird das Nahrungsmittel von oben mit Wasser beregnet und von unten mit Wasser besprüht. Das Vorwärmwasser wird mittels Dampf auf 60 °C gehalten.

Während des Blanchierschritts wird das Nahrungsmittel durch direkte Dampf injektion von unten weiter erwärmt. Zur Minimierung von Wasser- und Energieverbrauch wird der Dampf wiederverwendet und der Prozess in abgeschlossenen Geräten durchgeführt, die für die Minimierung des Dampfverbrauchs konzipiert sind.

Abschließend wird das Nahrungsmittel mittels leistungsstarker Gebläse luftgekühlt. Die Luft wird noch weiter, auf eine geringere Temperatur, abgekühlt, indem Wasser in den Luftstrom eingesprüht wird. Dieses Wasser verhindert das Austrocknen des Nahrungsmittels. Falls nötig, kann das Nahrungsmittel im letzten Kühlkompartiment noch weiter mit Wasser abgekühlt werden. Die Wiederverwendung des Kühlwassers im Vorwärmabschnitt ist nicht hilfreich, da das Wasser nicht viel Energie enthält. Luftkühlung ist weniger energieeffizient als Wasserkühlung, da die Wärme nicht wiederverwendet werden kann und die Gebläse, die zur Erzeugung des Luftstroms für das Nahrungsmittel erforderlich sind, viel Energie verbrauchen.

#### Erreichbare Umweltvorteile

Geringster Wasserverbrauch und geringste Abwassermenge im Vergleich zu den anderen Blanchiertechniken. Weniger Energieverbrauch im Vergleich zum Förderbandblanchieren mit Luftkühlung.

#### Medienübergreifende Auswirkungen

Höherer Energieverbrauch als beim Förderbandblanchieren mit Wasserkühlung und beim Trommelblanchieren mit Gegenstrom-Wasserkühlung. Hoher BSB im Abwasser.

#### Betriebsdaten

Die optimale Temperatur und Dauer des Blanchierens sind von der Art des Nahrungsmittels und der Größe der zu blanchierenden Stücke abhängig. Übliche Blanchierbedingungen sind: 65 – 95 °C für mindestens eine Minute. Beim Dampfblanchieren fällt Abwasser mit hohem BSB an.

Die Energieeffizienz kann von der Methode abhängen, mit der der Dampfdruck erhalten wird. Das Nahrungsmittel kann dem Blanchiergerät durch Drehschieber und Abdichtungen zugeführt und entnommen werden, um den Dampfverlust zu verringern und die Energieeffizienz zu verbessern, oder der Dampf kann mittels Venturi-Ventilen wiederverwendet werden. Mit der Verwendung einer Kombination aus hydrostatischen und Venturi-Ventilen kann die Effizienz noch weiter gesteigert werden.

Beim Dampfblanchieren sind den Angaben zufolge die Verluste an wasserlöslichen Bestandteilen und Nährstoffe geringer, aber die Blanchierwirkung kann ungleichmäßig sein, wenn das Nahrungsmittel zu hoch auf dem Förderband aufgeschüttet ist, bzw. Stellen, an denen sich Produkteinheiten berühren, werden möglicherweise nicht blanchiert.

#### Anwendbarkeit

Anwendbar für das Blanchieren von Obst und Gemüse.

#### Referenzliteratur

[1, CIAA, 2002, 31, VITO, et al., 2001, 87, Ullmann, 2001]

### **4.7.3.5.2 Förderbandblanchieren mit Wasserkühlung**

#### Beschreibung

Dabei handelt es sich um einen kontinuierlichen Prozess, bei dem das Nahrungsmittel auf einem langen perforierten Förderband bewegt wird. Das Nahrungsmittel wird vorgewärmt, indem es von oben mit Wasser beregnet und unten mit Wasser besprüht wird, das sich in Gegenrichtung zum Nahrungsmittel bewegt. Das Vorwärmwasser wird mittels Dampf auf 60 °C gehalten. Das abgekühlte Vorwärmwasser kann in anderen Verfahren wiederverwendet werden, z. B. beim Waschen und Schneiden oder beim Vorspülen z. B. von Gefriertunneln.

Im Blanchierabschnitt wird das Nahrungsmittel ebenfalls von oben mit Wasser beregnet und von unten mit Wasser besprüht. Für diesen Schritt wird die Wassertemperatur mittels Dampfinjektion bei 80 – 95 °C gehalten.

Zuletzt wird das Nahrungsmittel mit Wasser gekühlt. Das Abkühlen erfolgt in einer Reihe unterschiedlicher Kompartimente. In jedem Kompartiment wird Wasser auf und unter das Nahrungsmittel gesprüht. Frisches Kühlwasser, z. B. von 2 – 15 °C, tritt in das letzte Kompartiment des Kühlabschnitts ein und wird in den vorhergehenden Kompartimenten wiederverwendet. Das Wasser aus dem ersten Kompartiment des Kühlabschnitts, also sofort nach dem Blanchieren, das warm ist, wird im Vorwärmabschnitt wieder verwendet, sodass eine Wärmerückgewinnung und eine Verringerung des Wasserverbrauchs erfolgt. Wenn das kälteste verfügbare Wasser zur Kühlung genutzt wird, sinkt auch der Energieverbrauch, sowohl für den Kühlabschnitt nach

dem Blanchieren als auch in Fällen, in denen das Nahrungsmittel bei niedrigen Temperaturen gelagert oder verarbeitet werden soll, z. B. durch Tiefkühlung.

### Erreichbare Umweltvorteile

Geringster Energieverbrauch im Vergleich zu allen anderen Blanchiertechniken. Geringerer Wasserverbrauch als beim Trommelblanchieren mit Gegenstrom-Wasserkühlung.

### Medienübergreifende Auswirkungen

Höherer Wasserverbrauch im Vergleich zum Dampfblanchieren mit Luftkühlung und Förderbandblanchieren mit Luftkühlung. Hoher BSB im Abwasser.

### Betriebsdaten

Die optimale Temperatur und Dauer des Blanchierens hängen von Art und Größe des Nahrungsmittels ab. Beim Blanchieren mit heißem Wasser fällt Abwasser mit hohem BSB an.

Wenn ein Förderbandblanchierer mit Wasserkühlung kombiniert wird, werden 2 – 8 kWh<sub>e</sub>/t tiefgekühltes Produkt verbraucht. Das Förderbandblanchieren mit Wasserkühlung ist die energieeffizienteste Blanchiertechnik. Der Grund dafür besteht darin, dass die durch das Abkühlen des Nahrungsmittels in der Kühlzone freigesetzte Wärme zum Vorwärmen des Gemüses vor dem Blanchieren genutzt wird. Außerdem wird der Wasserverbrauch durch die Wiederverwendung des Wassers in den Kühlkompartimenten und für das Vorwärmen minimiert.

Tabelle 4.90 zeigt Energieträger und Verbrauch beim Förderbandblanchieren mit Wasserkühlung, bezogen auf die Menge des tiefgekühlten Produkts, d. h. es wird davon ausgegangen, dass das Produkt nach dem Blanchieren tiefgekühlt wird.

| Energieträger  | Ungefäher Verbrauch |
|--|---------------------|
| Heißwasser (kWh/t Tiefkühlgemüse)                      | 0*                  |
| Dampf (t/t Tiefkühlgemüse)                             | 0,09                |
| Dampfdruck (bar)                                       | 7                   |
| Strom (kWh <sub>e</sub> /t Tiefkühlgemüse)             | 2 – 9               |
| * 0, weil das Wasser durch Dampfinjektion erwärmt wird |                     |

**Tabelle 4.90: Energieträger und Verbrauch beim Förderbandblanchieren mit Wasserkühlung**

### Anwendbarkeit

Anwendbar für das Blanchieren von Obst und Gemüse.

### Referenzliteratur

[31, VITO, et al., 2001, 32, Van Bael J., 1998]

#### **4.7.3.5.3 Förderbandblanchieren mit Luftkühlung**

### Beschreibung

Dabei handelt es sich um einen kontinuierlichen Prozess, bei dem das Nahrungsmittel auf einem langen perforierten Förderband bewegt wird. Das Nahrungsmittel wird vorgewärmt, indem es von oben mit Wasser beregnet und unten mit Wasser besprüht wird, das sich in Gegenrichtung zum Nahrungsmittel bewegt. Das Vorwärmwasser wird mittels Dampf auf 60 °C gehalten. Das abgekühlte Vorwärmwasser kann in anderen Verfahren wiederverwendet werden, z. B. beim Waschen und Schneiden oder beim Vorspülen z. B. von Gefriertunneln.

Im Blanchierabschnitt wird das Nahrungsmittel von oben mit Wasser beregnet und von unten mit Wasser besprüht. Die Wassertemperatur wird mittels Dampfinjektion bei 80 – 95 °C gehalten.

Das blanchierte Nahrungsmittel wird mittels leistungsstarker Gebläse luftgekühlt. Die Luft wird noch weiter, auf eine geringere Temperatur, abgekühlt, indem Wasser in den Luftstrom eingesprüht wird. Das Wasser verhindert das Austrocknen des Nahrungsmittels. Falls nötig, kann das Nahrungsmittel im letzten Kühlkompartiment noch weiter mit Wasser abgekühlt werden. Die Wiederverwendung des Kühlwassers im Vorwärmabschnitt ist nicht hilfreich, da das Wasser nicht viel Energie enthält. Diese Technik ist weniger

energieeffizient, da bei der Luftkühlung die Wärme nicht wiederverwendet werden kann und die Gebläse, die für die Erzeugung des Luftstroms für das Nahrungsmittel erforderlich sind, viel Energie verbrauchen.

#### Erreichbare Umweltvorteile

Geringerer Wasserverbrauch im Vergleich zum Förderbandblanchieren mit Wasserkühlung und zum Trommelblanchieren mit Gegenstrom-Wasserkühlung.

#### Medienübergreifende Auswirkungen

Höchster Energieverbrauch im Vergleich zu allen anderen Blanchiertechniken. Größerer Wasserverbrauch als beim Dampfblanchieren mit Luftkühlung. Hoher BSB im Abwasser.

#### Betriebsdaten

Die optimale Temperatur und Dauer des Blanchierens hängen von Art und Größe des Nahrungsmittels ab. Beim Blanchieren mit heißem Wasser fällt Abwasser mit hohem BSB an.

Wenn ein Förderbandblanchierer mit Luftkühlung kombiniert wird, werden 7 – 28 kWh<sub>e</sub>/t tiefgekühltes Produkt verbraucht. Leistungsstarke Gebläse verbrauchen 60 kWh<sub>e</sub>. Tabelle 4.91 zeigt Energieträger und Verbrauch für den Förderbandblanchierer mit Luftkühlung, bezogen auf die Menge an tiefgekühltem Produkt.

| Energieträger  | Größenordnung |
|--|---------------|
| Heißwasser (kWh/t Tiefkühlgemüse)                      | 0*            |
| Dampf (t/t Tiefkühlgemüse)                             | 0,16          |
| Dampfdruck (bar)                                       | 7             |
| Strom (kWh <sub>e</sub> /t Tiefkühlgemüse)             | 7 – 30        |
| * 0, weil das Wasser durch Dampfinjektion erwärmt wird |               |

**Tabelle 4.91: Energieträger und Verbrauch beim Förderbandblanchieren mit Luftkühlung**

Bei der Verarbeitung von Konserven reicht es aus, das Nahrungsmittel auf etwa 40 °C abzukühlen, da es einer weiteren Behandlung mit Wärme unterzogen wird, die das Entstehen bakteriologischer Probleme unterbindet. Konserven werden in einer späteren Stufe, nämlich während der Sterilisation und Pasteurisation, einer Wärmebehandlung unterzogen. Das bedeutet, dass weniger Energie verbraucht wird, wenn diese Technik bei Konserven angewandt wird, als bei anderen Verwendungsformen im Obst- und Gemüsesektor, bei denen eine weitere Abkühlung nötig ist, z. B. vor dem Tiefkühlen.

#### Anwendbarkeit

Anwendbar für das Blanchieren von Obst und Gemüse.

#### Referenzliteratur

[31, VITO, et al., 2001, 32, Van Bael J., 1998]

### **4.7.3.5.4 Trommelblanchieren mit Gegenstrom-Wasserkühlung**

#### Beschreibung

Bei dieser Technik handelt es sich um ein Chargenverfahren, in dem Nahrungsmittel über eine Rinne und eine Förderschraube in das System eingebracht werden. Das Wasser für den Blanchierer wird mittels Dampfinjektion erwärmt. Das Nahrungsmittel verlässt das System durch ein Verschlusselement mit Stanzlöchern. Als nächstes wird das Produkt mit kaltem Wasser gekühlt, das im Gegenstrom zum Nahrungsmittel fließt. Das erwärmte Kühlwasser kann in anderen Verfahren wiederverwendet werden, z. B. zum gleichzeitige Vorwärmen des frischen Nahrungsmittels und dessen Transport in die Blanchiertrommel.

#### Erreichbare Umweltvorteile

Geringerer Energieverbrauch im Vergleich zum Förderbandblanchieren mit Luftkühlung und Dampfblanchieren mit Luftkühlung.

#### Medienübergreifende Auswirkungen

Höchster Wasserverbrauch im Vergleich zu allen anderen Blanchiertechniken. Hoher BSB im Abwasser. Höherer Energieverbrauch als beim Förderbandblanchieren mit Wasserkühlung.

### Betriebsdaten

Die optimale Temperatur und Dauer des Blanchierens hängen von Art und Größe des Nahrungsmittels ab. Beim Trommelblanchieren mit Gegenstrom-Wasserkühlung werden 1 bis 2,6 kWh/t tiefgekühltes Produkt verbraucht. Der Gegenstrom-Trommelkühler verbraucht 2 – 4 Liter Wasser pro Kilogramm Nahrungsmittel.

Tabelle 4.92 zeigt Energieträger und Verbrauch für das Trommelblanchieren, bezogen auf die Menge an tiefgekühltem Produkt, d. h. es wird davon ausgegangen, dass das Produkt nach dem Blanchieren tiefgekühlt wird.

| Energieträger  | Ungefährer Verbrauch |
|--|----------------------|
| Heißwasser (kWh/t Tiefkühlgemüse)                      | 0*                   |
| Dampf (t/t Tiefkühlgemüse)                             | 0,16                 |
| Dampfdruck (bar)                                       | 7                    |
| Strom (kWh/t Tiefkühlgemüse)                           | 0,5 – 1,3            |
| * 0, weil das Wasser durch Dampfinjektion erwärmt wird |                      |

**Tabelle 4.92: Energieträger und Größenangaben beim Trommelblanchieren**

Tabelle 4.93 zeigt Energieträger und Verbrauch für die Gegenstrom-Wasserkühlung bezogen auf die Menge an tiefgekühltem Produkt, d. h. es wird davon ausgegangen, dass das Produkt nach dem Blanchieren tiefgekühlt wird.

| Energieträger                     | Ungefährer Verbrauch |
|-----------------------------------|----------------------|
| Heißwasser (kWh/t Tiefkühlgemüse) | 0                    |
| Dampf (t/t Tiefkühlgemüse)        | 0                    |
| Dampfdruck (bar)                  | 0                    |
| Strom (kWh/t Tiefkühlgemüse)      | 0,5 – 1,3            |

**Tabelle 4.93: Energieträger und Verbrauch bei der Gegenstrom-Wasserkühlung**

### Anwendbarkeit

Anwendbar für das Blanchieren von Obst und Gemüse.

### Referenzliteratur

[31, VITO, et al., 2001, 32, Van Bael J., 1998, 232, Fellows P J, ]

### **4.7.3.6 Kühlung von Obst und Gemüse vor dem Tiefkühlen**

#### Beschreibung

Die Temperatur von Obst und Gemüse beim Eintritt in den Gefriertunnel ist ein wichtiger Faktor, der auch den Energieverbrauch des Systems bestimmt. Je geringer die Temperatur, desto geringer die Kühllast und der Energieverbrauch. Die Temperatur von Obst und Gemüse kann gesenkt werden, indem sie ausreichend lange mit ausreichend kaltem Wasser in Berührung gebracht werden. Dabei handelt es sich im Allgemeinen um den Kühlschritt nach dem Blanchieren. Wenn die Umgebungstemperatur des Wassers über 4 °C liegt, kann eine Eiswasserrinne benutzt werden, um Obst und/oder Gemüse auf 4 °C abzukühlen. Zusätzlich kann das zirkulierende Wasser in der Eiswasserrinne kontinuierlich durch einen darin eingebauten Wasserkühler gekühlt werden (siehe Abbildung 4.52), oder indem eine Verdampferplatte unter der Eiswasserrinne angebracht wird (siehe Abbildung 4.53). Die Verdampferplatte wird in ähnlicher Weise in das Tiefkühlsystem integriert wie der Wärmetauscher für die Eiswasserherstellung. Wenn das Wasser in den Gefriertunnel eintritt, gefriert es, was eine zusätzliche Energielast bedeutet. Das lässt sich vermeiden, indem das Nahrungsmittel über ein vibrierendes Sieb oder ein perforiertes Förderband geführt wird, sodass das Wasser vom Nahrungsmittel getrennt und zur Wiederverwendung im Kühlprozess aufgefangen werden kann.

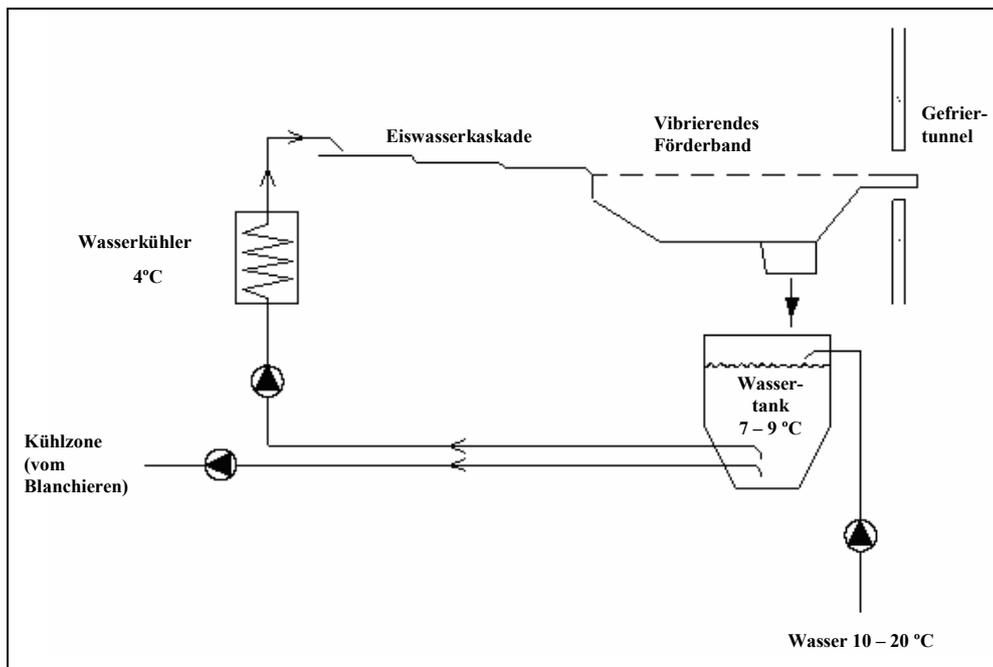


Abbildung 4.52: Installation eines Wasserkühlers in einer Eiswasserrinne

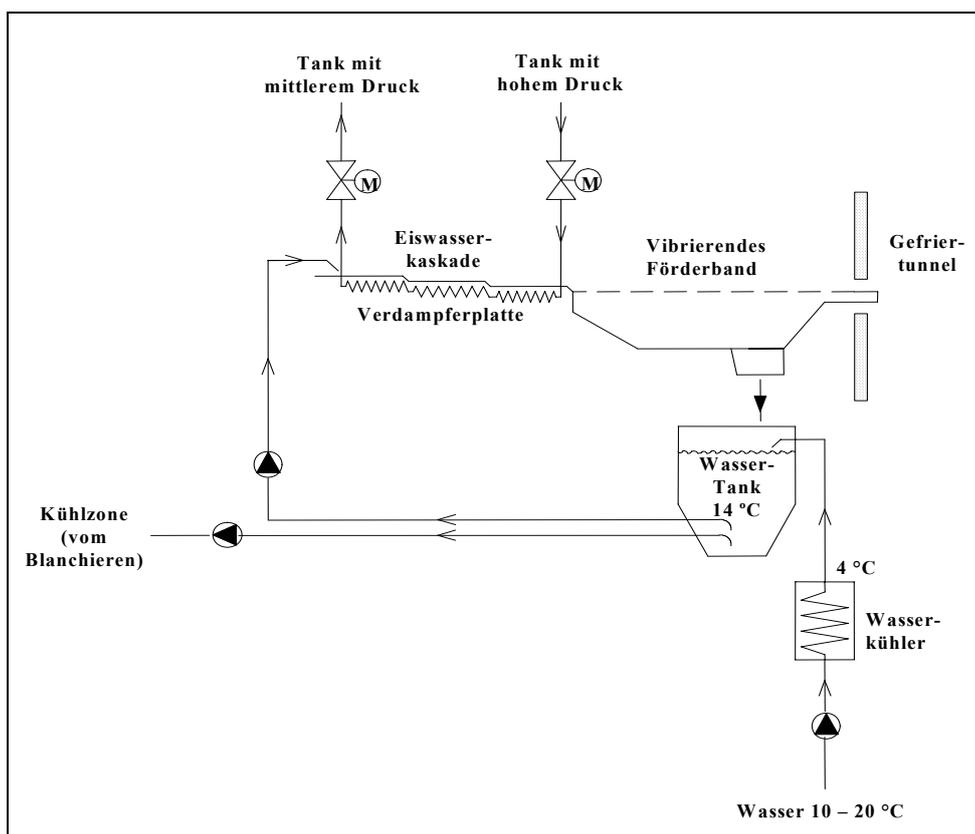


Abbildung 4.53: Installation einer Verdampferplatte unter der Eiswasserrinne

Erreichbare Umweltvorteile

Weniger Energieverbrauch beim Tiefkühlen.

Medienübergreifende Auswirkungen

Energieverbrauch im Kühlprozess vor dem Tiefkühlen.

### Betriebsdaten

Angaben zufolge führt eine Absenkung der Produkttemperatur um 10 °C zu:

- einer Absenkung der Kompressorlast für das Kühlen bei -30 bis -40°, die den Stromverbrauch um 5 bis 7 kWh<sub>e</sub>/t senkt,
- einer Zunahme der Kompressorlast für das Kühlen bei 0 °C, die den Stromverbrauch um 1,5 bis 2 kWh<sub>e</sub>/t senkt,
- einer Gesamtabenkung der elektrischen Last um 3 bis 5,5 kWh<sub>e</sub>/t.

Es wird auch angegeben, dass bei einem Gefriertunnelbetrieb mit einer Produktdurchsatzrate von 10 t/h die elektrische Last um 30 bis 55 kW absinkt, wenn die Obst- oder Gemüsetemperatur vor dem Eintritt in den Gefriertunnel von 30 auf 20 °C abgesenkt wird. Außerdem ist beim Kühlen mit Wasser der Wärmeaustausch um eine Größenordnung stärker als bei der Kühlung mit Luft. Außerdem gilt, dass Obst und Gemüse so kalt und trocken wie möglich in den Gefriertunnel transportiert werden sollten, um die Gefrierlast zu verringern. Durch das Abtropfenlassen von Obst und Gemüse unmittelbar nach dem Eintauchen in das kalte Wasser wird dies gefördert.

### Anwendbarkeit

Wird beim Tiefkühlen von Obst und Gemüse angewandt.

### Referenzliteratur

[31, VITO, et al., 2001, 32, Van Bael J., 1998]

#### **4.7.3.7 Wiederverwendung von Wasser bei der Obst- und Gemüseverarbeitung**

##### Beschreibung

In neuen und bestehenden Anlagen kann es Möglichkeiten geben, Wasser entweder direkt in einem Arbeitsgang oder indirekt als Wärme- oder Kältequelle wiederzuverwenden. Insbesondere in bestehenden Anlagen sind solche Möglichkeiten je nach durchgeführten Arbeitsgängen, den am Standort vorhandenen Einrichtungen zur Wasserbehandlung und den hygienischen Anforderungen an das am Standort verwendete Wasser abhängig. Es kann möglich sein, Wasser in demselben Arbeitsgang entweder ganz ohne Behandlung oder nach einer einfachen Filtration wiederzuverwenden.

Eine systematische Untersuchung, wie sie in Abschnitt 4.1.6.4.1 beschrieben wird, bei der sämtliche Verwendungsarten von Wasser und die für jede Verwendung und Wiederverwendung erforderliche Qualität berücksichtigt werden, kann vorgenommen werden. Tabelle 4.94 zeigt ein Beispiel für eine Tabelle zur Aufzeichnung solcher Möglichkeiten.

|   |   | BEISPIELE                                    |   |   |   |  |
|---|---|--|---|---|---|--|
|   |   |  | A   | B | C   | D  |
| B<br>E<br>I<br>S<br>P<br>I<br>E<br>L<br>E |   | <b>Wieder-<br/>verwendung<br/>von Wasser</b> | Prozesstechniken, die keine vollständige Abwasserbehandlung erfordern (Angabe, welche Behandlung zuerst erforderlich ist, z. B. Sieben oder Desinfektion) |   | Reinigung (möglichst Unterscheidung zwischen verschiedenen Reinigungsschritten) | Alle Arbeitsgänge, die Trinkwasserqualität erfordern |
|   |   | <b>Wasser-<br/>verwendung</b>                |   |   |   |  |
|   | 1 |  |   |   |   |  |
|   | 2 |  |   |   |   |  |
|   | 3 |  |   |   |   |  |
|   | 4 |  |   |   | Nach der Filtration Gemüsestücke entfernen                                      |  |
|   | 5 |  |   |   |   |  |
|   | 6 | Indirekte Kühlung (keine Produktberührung)   |   |   |   |  |
|   | 7 |  |   |   |   |  |
| 8   |   |  |   |   |   |  |

Tabelle 4.94: Beispiele für die Wiederverwendung von Wasser im Obst- und Gemüsektor

Erreichbare Umweltvorteile

Weniger Wasserverbrauch und, falls Warmwasser verwendet wird, geringerer Energieverbrauch.

Medienübergreifende Auswirkungen

Wenn vor der Wiederverwendung eine Behandlung erforderlich ist, wird Energie verbraucht, und möglicherweise werden auch Chemikalien verbraucht.

Betriebsdaten

Für den Obst- und Gemüsektor wird über die Trennung von Regenwasser, Waschwasser (z. B. Wasser vom Waschen von Rohstoffen und aus Reinigungsschritten) und Prozesswasser (z. B. Wasser, das beim Schälen, Sortieren und Einmachen anfällt) berichtet. Außerdem kann Wasser, das lediglich zum Waschen ankommender Produkte verwendet wurde und einen geringen BSB hat, einfach gesiebt anstatt einer vollen Behandlung unterzogen werden. Dasselbe gilt für Tiefkühlabtauwasser.

Zum Beispiel wird beim Förderbandblanchieren mit Wasserkühlung das Wasser aus dem ersten Kompartiment des Kühlabschnitts, also unmittelbar nach dem Blanchieren, das warm ist, zum Vorwärmen vor dem Blanchieren wiederverwendet, d. h. Wärme wird rückgewonnen und durch die Rückführung wird weniger Wasser verbraucht. Es wird auch angegeben, dass bei manchen Obst- und Gemüsesorten das Blanchierwasser für die Vorreinigung der Gefriertunnel verwendet werden kann.

Wasser, das zum Blanchieren verwendet wird, und Wasser, das zum Kühlen nach dem Blanchieren verwendet wird, kann ohne Behandlung zum Waschen von Rohstoffen verwendet werden.

Wasser, das zum Garen von Obst und Gemüse verwendet wird, kann ebenfalls ohne Behandlung zum Waschen von Rohstoffen eingesetzt werden.

Angaben zufolge kann Wasser, das zum Kühlen von Dosen und Gläsern bei der Konservierung von Obst und Gemüse verwendet wird, nach der Sterilisation der Dosen und Gläser als Kühlwasser, zum Waschen von Rohstoffen, zum Waschen von geschältem Obst und Gemüse, zum Erwärmen von kaltem Wasser beim Blanchieren oder als Reinigungswasser verwendet werden.

Es wird auch angegeben, dass Wasser aus Sterilisationsprozessen für das Vorwaschen von Rohstoffen eingesetzt werden kann. Wenn dieses Wasser erwärmt wird, kann es die Haltbarkeitsdauer des Nahrungsmittels beeinträchtigen, weil Bakterienwachstum gefördert wird. Die Wiederverwendung von erwärmtem Wasser für das Waschen kann davon abhängen, ob das Obst bzw. Gemüse später einer Wärmebehandlung unterzogen wird.

Nach einer biologischen Abwasserbehandlung und Chlorierung kann Wasser für das Reinigen von Böden wiederverwendet werden.

Nach einer biologischen Behandlung kann Wasser von der Umkehrosmose und der UV-Desinfektion für Zwecke eingesetzt werden, die Trinkwasserqualität erfordern. Ein berichtetes Beispiel beschreibt die Wiederverwendung von Wasser zum Waschen von Salat (siehe Abschnitt 4.5.7.3.4).

### Anwendbarkeit

In neuen und bereits bestehenden Anlagen anwendbar. Durch die Verbesserung der Wiederverwendung von Wasser in bestehenden Anlagen mit Geräten, die später durch BVT ersetzt werden sollen, kann es möglich sein, Wasser wiederzuverwenden und so die Umweltauswirkungen der bestehenden Geräte zu minimieren.

### Anlass für die Umsetzung

Geringerer Wasserverbrauch, und in manchen Fällen auch geringerer Energieverbrauch.

### Referenzliteratur

[31, VITO, et al., 2001, 200, CIAA, 2003]

## **4.7.4 Pflanzliche Öle und Fette**

### **4.7.4.1 Zweiphasenextraktion von Olivenöl**

#### Beschreibung

Die Olivenölproduktion ist seit jeher eine der wesentlichen Ursachen industrieller Verunreinigung in Gegenden, in denen sie stattfindet, z. B. im spanischen Andalusien. Bei der traditionellen Olivenverarbeitung, also der dreiphasigen Produktion, führt die Extraktion der Olivenkerne zu drei Strömen, nämlich ölig, wässrig und fest.

Der ölige Strom ist das native Öl. Es wird mit einer Ausbeute von etwa 200 kg/t Oliven erzeugt, wenn eine kontinuierliche Abscheidung über Dekantierzentrifugen erfolgt, oder mit 150 kg/t bei Verwendung von Olivenölpresen.

Der wässrige Abfall, also das Abwasser, wird manchmal als „Fruchtwasser“ bezeichnet und ist stark verschmutzt. Das Volumen ist von der eingesetzten Technik abhängig, aber im Allgemeinen entsteht 1 m<sup>3</sup> Abwasser pro Tonne verarbeiteter Oliven. Die spezifische Belastung wird auf etwa 65 kg BSB<sub>5</sub>/t verarbeiteter Oliven geschätzt. Zu Anfang der 1990er Jahre entsprach das während einer 100-tägigen Verarbeitungskampagne anfallende Abwasser etwa derselben Menge Abwasser, die die Gesamtbevölkerung Andalusiens im ganzen Jahr produzierte. Damals kamen nur die klassischen Pressen und die dreiphasige kontinuierliche Abscheidung mit Dekantierzentrifugen zur Anwendung.

Der Festabfall besteht im Wesentlichen aus zwei Teilen, nämlich den Steinen und dem rohen Ölkuchen/Trester. Die Steine fallen in Anlagen an, in denen entsteinte oder gefüllte Speiseoliven hergestellt werden. Sie können als Brennstoff zum Heizen, als Baumaterial oder für die Aktivkohleherstellung genutzt werden. Der Ölkuchen aus der ersten Pressung der Oliven enthält noch eine kleine Ölmenge, die extrahiert werden kann. Sein Wassergehalt und seine Zusammensetzung hängen von der jeweiligen Extraktionstechnik ab. Wenn der Ölkuchen nicht zur Verarbeitung, also Extraktion, weitergeleitet wird, wird er oft als Brennstoff zum Heizen oder Tierfutterergänzung benutzt, oder in den Olivenhain zurückgebracht und als Mulch zur Bodenverbesserung verwendet.

Bei einer neuen Technik, die erstmals 1991/1992 zum Einsatz kam, werden die Dekantierzentrifugen so modifiziert, dass die ausgepressten (gemischten) Oliven in zwei Phasen, nämlich eine ölige Phase und eine feste

Phase, getrennt werden. Dabei muss dem Olivengemisch kein Wasser zugesetzt werden. Bis 2000 waren praktisch alle andalusischen Olivenölmühlen auf den zweiphasigen Prozess umgestellt.

In Abbildung 4.54 wird die Anwendungshäufigkeit des Zweiphasen- und des Dreiphasen-Olivenölverfahrens in Andalusien verglichen.

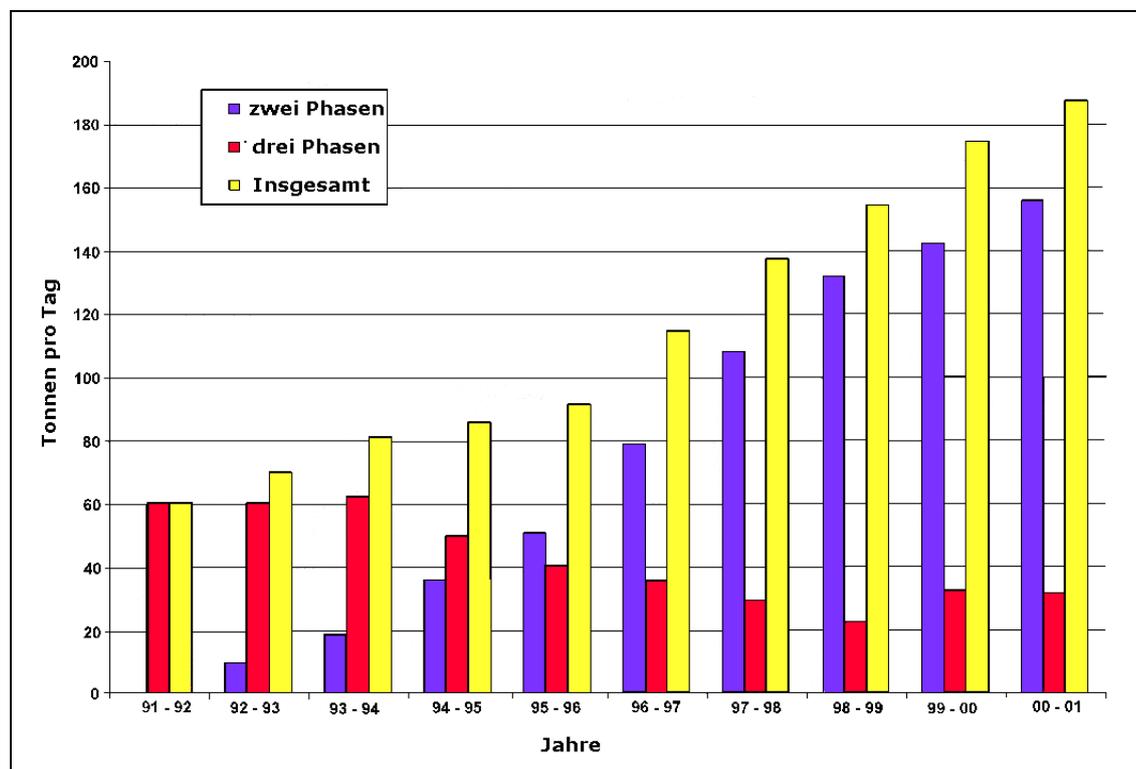


Abbildung 4.54: Zweiphasen- und das Dreiphasen-Olivenölextraktionsverfahren [86, Junta de Andalucia and Agencia de Medio Ambiente, 1994]

#### Erreichbare Umweltvorteile

Im Extraktionsteil des zweiphasigen Prozesses wird Wasser eingespart. Abwassermenge und Abwasserfracht werden ebenfalls reduziert. Die Wassereinsparungen sind besonders wichtig, da Oliven in Gegenden mit wenig Niederschlägen angebaut und verarbeitet werden. Durch die ländliche Lage eines wesentlichen Teils dieser Branche gibt es oft auch nur wenig Zugang zu kommunalen Kläranlagen. Der nassere Festabfall gilt als geringeres Problem als das Abwasser, das im dreiphasigen Prozess anfällt.

#### Medienübergreifende Auswirkungen

Das feste Abfallprodukt, also der Kuchen oder Trester (im Spanischen „alpeorujo“) fällt in größeren Mengen an als beim dreiphasigen Prozess und enthält 7 – 21 % mehr Wasser. Nach einer Hexanextraktion entsteht der sogenannte ausgepresste Ölkuchen. Er wird oft als Brennstoff zum Heizen oder als Tierfutterergänzung verwendet, oder als Mulch in den Olivenhain zurückgebracht. Vor der Entsorgung wird der ausgepresste Ölkuchen normalerweise getrocknet. Der Energiebedarf und die Trocknungskosten sind höher und das Trocknen ist schwieriger, da der "alpeorujo" mehr Wasser, Polysaccharide und Polyphenole enthält.

#### Betriebsdaten

Im Extraktionsteil des zweiphasigen Prozesses wird kein Wasser verwendet, daher braucht auch kein Wasser behandelt zu werden. Die Energieeinsparung beträgt etwa 20 %. Abwassermenge und -fracht sind geringer. Im traditionellen Verfahren führte die Verarbeitung von 1 Tonne Oliven zur Produktion von etwa 1 m<sup>3</sup> Abwasser mit einem durchschnittlichen BSB<sub>5</sub> von 60.000 mg/l. Die Abwassermenge aus dem zweiphasigen Verfahren beträgt etwa 0,3 m<sup>3</sup>/Tonne Oliven, mit einem durchschnittlichen BSB<sub>5</sub> von 20.000 mg/l, sodass die Verschmutzungsfracht etwa 1/10 beträgt. Da kein Wasser für die Extraktion verwendet wird, kommt es auch zu Einsparungen beim Wasserverbrauch.

Es gibt Schwierigkeiten beim Umgang mit dem Ölkuchen, der einen höheren Feuchtigkeitsgehalt hat als der traditionelle Kuchen und von traditionellen Extraktionsanlagen nicht angenommen wird. Es ist nach den

Angaben auch weniger rentabel, Öl daraus zu extrahieren, da der Ölgehalt im Vergleich zu den traditionellen oder dreiphasigen Systemen geringer ist. In allen Fällen stellt die Kompostierung angabegemäß einen gangbaren Weg dar. Als Biomassebrennstoff kann der Ölkuchen den Angaben zufolge verwendet werden, wenn er in ausreichender Menge vorliegt, also nicht bei einzelnen, weit verstreut und abgeschieden gelegenen Anlagen.

Die Durchsätze des zweiphasigen und des dreiphasigen Olivenölverfahrens werden in Tabelle 4.95 verglichen.

|        |  | Zweiphasenprozess    |                                  | Dreiphasenprozess                 |                     |
|--------|--|----------------------|----------------------------------|-----------------------------------|---------------------|
|        |  | IMPEL-Projekt-daten  | Spanische Daten                  | IMPEL-Projekt-daten               | Spanische Daten     |
| Zufuhr | Oliven (t)   | 1                    | 1                                | 1                                 | 1                   |
|        | Wasser (t oder m <sup>3</sup> )                          | 0                    | 0                                | 0,5                               | 0,7 – 1             |
| Abgabe | Öl (t)   | 0,18                 | 0,2                              | 0,18                              | 0,2                 |
|        | Abwasser (t oder m <sup>3</sup> )                        | 0                    | 0                                | 0,72                              | 1 – 1,2             |
|        | Trester (t)  | 0,82                 | 0,8                              | 0,60                              | 0,5 – 0,6           |
|        | Organische Schadstoffe (pro Tonne produziertes Olivenöl) | 1,5<br>(als Trester) | 27<br>(als Abwasser und Trester) | 1,5<br>(als Abwasser und Trester) | 27<br>(als Trester) |

Tabelle 4.95: Vergleich der Durchsätze beim Dreiphasen- und Zweiphasen-Ölivenölverfahren

Bei der Zweiphasenextraktion von Olivenöl entfällt die Notwendigkeit, heißes Wasser zuzusetzen. Der Energieverbrauch liegt den Angaben zufolge bei beiden Systemen bei <90 – 117 kWh/t. Beide Systeme benötigen auch dieselbe Menge an Waschwasser, nämlich 0,08 – 0,3 m<sup>3</sup>/t Oliven. Der Wasserverbrauch ist vom Extraktionsprozess unabhängig, obwohl es sich manchmal mit dem Abwasser oder dem nassen Trester aus dem Extraktionsprozess vermischt. Manchmal kommen die Mühlen ohne Waschwasser aus, da die Oliven direkt vom Baum gerntet werden.

In Spanien werden die Gesamtausbeuten für die zweiphasige und dreiphasige Olivenölextraktion für die Ernte 2004 - 2005 mit 20,68 % bzw. 20,29 % angegeben.

Anwendbarkeit

Vorhandene Dreiphasen-Dekanterzentrifugen können für den Zweiphasenbetrieb umgerüstet werden. Trester-trockner, die ursprünglich nach der Dreiphasenextraktion genutzt wurden, sind nicht für die Trocknung des bei der Zweiphasentechnik anfallenden Tresters geeignet. Im Vergleich zu dem bei der Dreiphasen-Extraktionstechnik produzierten Trester enthält der bei der Zweiphasentechnik anfallende Trester sowohl viel mehr Feuchtigkeit als auch organische Schadstoffe. Wenn der Zweiphasentrester nicht unter geeigneten Bedingungen getrocknet wird, kann das daraus hergestellte Öl PAK-Konzentrationen enthalten, die über den im Rahmen der Bestimmungen zur Lebensmittelsicherheit festgesetzten Werten liegen (Verordnung (EG) Nr. 208/2005 der Kommission vom 4. Februar 2005 zur Änderung der Verordnung (EG) Nr. 466/2001 im Hinblick auf polyzyklische aromatische Kohlenwasserstoffe (Text von Bedeutung für den EWR)).

Wirtschaftliche Aspekte

Es werden Einsparungen bei Wasser-, Energie- und Abwasserbehandlungskosten erzielt. Die Preise der Dekantierzentrifugen für die Zweiphasentrennung sind etwa genauso hoch wie die Preise der Dekantierzentrifuge für die Dreiphasentrennung. Der Trockner für Kuchen/Trester kann mehr als die Dekantierzentrifuge kosten, aber diese Kosten können sich kleinere benachbarte Mühlen teilen. Die Kosten für das Austauschen der "Dreiphasentrockner" gegen "Zweiphasentrockner" können für kleine abgelegene Anlagen prohibitiv hoch sein, da keine Skaleneffekte eintreten und/oder nicht die Möglichkeit besteht, die Kosten mit einer Reihe benachbarter Anlagen zu teilen.

Die Betriebskosten in einer Beispiel-Extraktionsanlage sanken um 12 – 24 EUR pro Tonne produziertes Olivenöl. In Andalusien erreichte die neue Technik innerhalb der ersten zwei Jahre einen Anteil von 30 %. Es wurde geschätzt, dass während der Ernten 1992/93 und 1993/94 1.150 Millionen ESP (etwa 6,9 Millionen EUR) bzw. 7.200 Millionen ESP (etwa 43,3 Millionen EUR) investiert wurden.

Anlässe für die Umsetzung

Einhaltung der Vorgaben für die Abwassereinleitung für einen Wachstumssektor. Staatliche Unterstützung beim Umgang mit dem erzeugten Festabfall.

Die Vorteile und Nachteile des Zweiphasensystems im Vergleich zu den traditionellen Systemen sind in Tabelle 4.96 zusammengefasst.

| Vorteile   | Nachteile  |
|--|--|
| Weniger flüssiger Abfall   | Es fällt immer noch stark kontaminiertes Abwasser an (BSB etwa 20.000 mg/l), sodass eine Abwasserbehandlung erforderlich ist |
| Wassereinsparung   | Der Wassergehalt des Festabfalls ist erheblich höher   |
| Geringere Produktionskosten  | Höhere Kosten für Lagerung und Transport des Festabfalls   |
| Es wird mehr Olivenöl produziert (größere Ausbeute und weniger Nebenprodukte). | Höhere Kosten für das Trocknen des Festabfalls   |
| Nachrüstung der bestehenden Systeme ist einfach und kostengünstig              | Höherer Zuckergehalt im Festabfall kann bei der Trocknung zu Problemen durch Karamellisierung führen.                        |

**Tabelle 4.96: Vor- und Nachteile des Zweiphasensystems im Vergleich zu den Dreiphasensystemen bei der Olivenölproduktion**

Beispielanlagen

Fast alle spanischen und mehr als die Hälfte der kroatischen Olivenölanlagen. Etwa 25 % der Olivenöl-extraktionsunternehmen in Europa.

Referenzliteratur

[86, Junta de Andalucia and Agencia de Medio Ambiente, 1994, 142, IMPEL, 2002, 211, IMPEL, 2003, 212, The olive oil source, 2004, 251, EC, 2005, 252, Greece, 2005, 253, Spain, 2005]

#### 4.7.4.2 Im Gegenstromverfahren arbeitende Desolventierer-Toaster (DT) bei der Extraktion pflanzlicher Öle

Beschreibung

Nach der Ölextraktion enthält das Schrot etwa 25 – 40 % Lösemittel. Das Lösungsmittel wird im Desolventierer-Toaster (DT) durch Verdampfung mit direktem und indirektem Dampf entfernt. Das DT-Gehäuse verfügt über mehrere Vordesolventierungs- und Desolventierungs-/Stripping-Böden. Das Schrot aus dem Extraktor tritt oben in den DT ein und erreicht den ersten Vordesolventierungsboden. Die Vordesolventierungsböden werden nur indirekt mit Dampf beheizt, um eine spontane Verdampfung des Lösemittels an der Oberfläche auszulösen. Hierdurch wird die in den Stripping-Abschnitten auf dem Schrot kondensierende Wassermenge verringert, sodass die benötigte Energiezufuhr für die anschließende Schrotrocknung gesenkt wird.

Über einen im unteren Teil des DT befindlichen Sprühdampfboden wird direkter Dampf in das System eingebracht. Der Dampf wandert dann durch die Schrotschichten auf den einzelnen Böden. Durch die Kondensation des Dampfes auf dem Schrot wird diesem ein Großteil des darin enthaltenen Hexans entzogen. Im DT bewegt sich der eingesprühte Frischdampf in echtem Gegenstrom zum Schrot. Der Dampfverbrauch wird durch den Gegenstrom und den Einsatz von Vordesolventierungsböden minimiert. Brüden von den Stripping-Böden und den Vordesolventierungsböden werden innerhalb des DT-Gehäuses zusammengeführt und an anderer Stelle im Extraktionsprozess als Wärmemedium in der Miscella-Destillation nach dem Waschen (siehe Abschnitt 4.7.4.3) wiederverwendet. Durch den Kontakt von Dampf und Schrot findet auch eine Toastung statt. Beim Toastprozess werden die Enzyme deaktiviert, sodass eine optimale Proteinqualität des Schrots für dessen Verwendung als Tierfutter gewährleistet und seine Verdaulichkeit verbessert wird.

Abbildung 4.55 zeigt das Flussbilddiagramm eines Gegenstrom-DT.

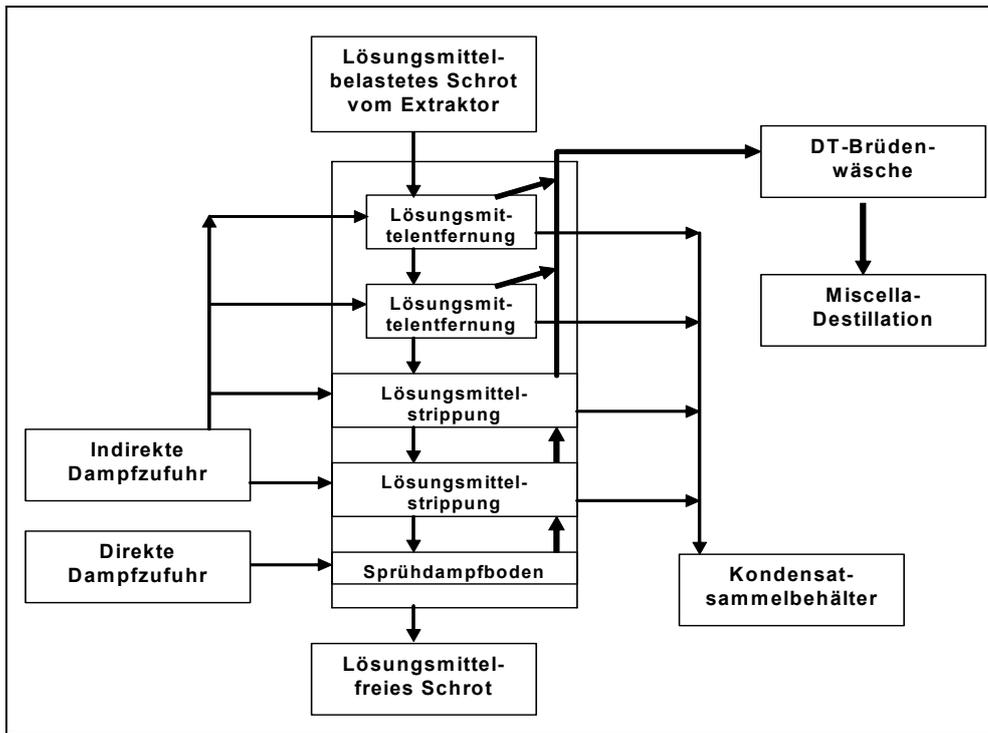


Abbildung 4.55: Grundfließbild eines Gegenstrom-DT

Erreichbare Umweltvorteile

Verringerung der Menge des im Schrot verbleibenden Lösemittels und damit des Lösemittelverlusts an die Umwelt. Verringerung des Dampfverbrauchs für das Desolventieren und die Schrotttrocknung. Geringeres Abwasservolumen. Ausgeglichenere Wärmeintegration mit dem Miscella-Destillationssystem, wodurch Kälte- und Wärmezufuhrbedarf sinken.

Betriebsdaten

Der Energieverbrauch wird normalerweise für den DT und das nachgeschaltete Trocknungsverfahren insgesamt angegeben. So wird beispielsweise bei der Vordesolventierung mittels indirektem Dampf auf den oberen Böden die in den Stripping-Abschnitten auf dem Schrot kondensierende Wassermenge im Vergleich zum Einsatz von direktem Dampf reduziert. Dadurch wird auch der Energiebedarf für den anschließenden Schrot-trocknungsschritt gesenkt. Tabelle 4.97 enthält Daten zum Energieverbrauch des DT und der nachgeschalteten Trocknung bei der Extraktion von Ölsaaten.

|                      |                |       |
|----------------------|----------------|-------|
| Dampf zum Erwärmen   | 15,55 – 31,11  | kWh/t |
|                      | 56 – 112       | MJ/t  |
|                      | 20 – 40        | kg/t  |
| Dampf für Strippung  | 54,44 – 116,66 | kWh/t |
|                      | 196 – 420      | MJ/t  |
|                      | 70 – 150       | kg/t  |
| Strom für DT-Antrieb | 2 – 5          | kWh/t |
|                      | 7 – 18         | MJ/t  |

Tabelle 4.97: Energieverbrauch des DT und der nachgeschalteten Trocknung bei der Extraktion von Ölsaaten

Den Angaben zufolge ermöglicht der Gegenstrom dem Betreiber, gleichzeitig eine akzeptable Lösemittel-restkonzentration in dem den DT verlassenden Schrot zu erzielen und sowohl den Hexanverlust im Extraktions-verfahren als auch die Temperatur des Brüden-gemisches, das den DT verlässt, zu reduzieren. Bei höheren Brüden-temperaturen steigt der Verbrauch von indirektem Dampf an.

Der DT-Brüden wird im ersten Verdampfer des Miscella-Destillationssystems (siehe Abschnitt 4.7.4.3). wiederverwendet. Die letzte Verdampfung und die letzte Strippung werden mit Dampf abgeschlossen. Das Kondensat-gemisch aus Wasser und Lösemittel wird in einem Hexan-Wasser-Abscheider getrennt. Das Hexan

wird wiederverwendet und das Abwasser an die Kläranlage abgegeben. Das Abwasser enthält nur CSB und Kjeldahl-Stickstoff.

#### Anwendbarkeit

Geeignet für neue und bereits bestehende Anlagen. Die Technik ist leicht verfügbar und arbeitet sehr zuverlässig.

#### Wirtschaftliche Aspekte

Hohe Investitionskosten. Rückgang der Energiekosten für die Extraktionsanlage.

#### Anlass für die Umsetzung

Potenziell geringere Lösemittelrückstände im Schrot. Senkung der Betriebskosten der Anlage. Erhöhte Anlagensicherheit. Betriebssicherheit des nachgeschalteten Prozesses. Erfüllung gesetzlicher Auflagen zur VOC-Vermeidung.

#### Referenzliteratur

[141, FEDIOL, 2002]

### 4.7.4.3 Wiederverwendung des DT-Brüdens im Miscella-Destillationssystem bei der Extraktion pflanzlicher Öle

#### Beschreibung

Mit dem DT wird dem Schrot das Hexan entzogen (siehe Abschnitt 4.7.4.2). Der Brüden aus dem DT-Schritt (Dampf-Hexan-Gemisch) wird in die erste Stufe des Vorverdampfers der Miscella-Destillation eingeleitet und dient dort als Wärmequelle, sodass eine Wärmerückgewinnung stattfindet. Ein Grundfließbild der Brüden-Wärme-Integration im DT ist in Abbildung 4.56 dargestellt.

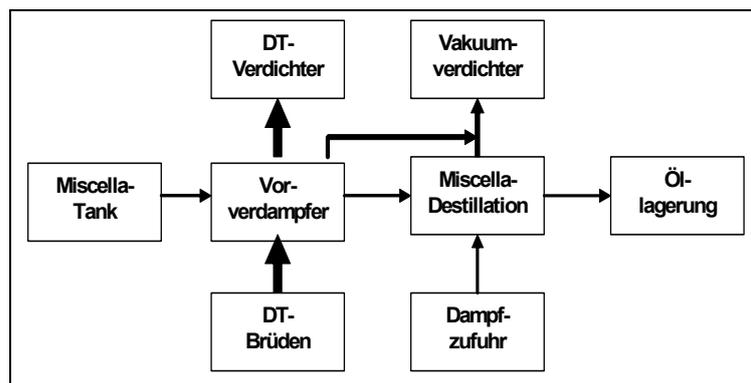


Abbildung 4.56: Grundfließbild der Brüden-Wärme-Integration im DT

#### Erreichbare Umweltvorteile

Geringerer Energie- und Lösemittelverbrauch.

#### Betriebsdaten

Die angegebenen Energieeinsparungen beim Extraktionsprozess belaufen sich auf etwa 37,5 kWh/t (135 MJ/t) (60 kg Dampf/Tonne) Saat. Energie wird auch eingespart, indem die Wärmefracht für das Kühlwassersystem der Anlage verringert wird.

Im Vorverdampfer steigt die Miscella-Konzentration (% Öl im Hexan/Öl-Gemisch) von etwa 20 – 30 % auf 60 – 75 % an. So kann beispielsweise bei der Verarbeitung von Soja die Anordnung des Vorverdampfers je nach Verfügbarkeit der DT-Brüdenabwärme zu einer Verdampfung von etwa 0,4 Tonnen Hexan pro Tonne Saat führen. Das stellt einen wesentlichen Anteil der Zufuhr frischen Lösemittels zur Extraktion dar. Durch die Wiederverwendung der Energie wird die Wärmelast für den DT-Kondensator verringert. Auch der Dampfbedarf der nachgeschalteten Miscella-Destillation geht zurück.

#### Anwendbarkeit

Bei der Extraktion von Ölsaaten in vielen Bereichen anwendbar. Die Technik ist leicht verfügbar und arbeitet sehr zuverlässig.

### Wirtschaftliche Aspekte

Hohe Investitionskosten. Reduzierung der Anlagenbetriebskosten durch Energierückgewinnung.

### Anlass für die Umsetzung

Optimierung der Energiebilanz der Miscella-Destillation. Erhöhte Anlagensicherheit. Einhaltung von staatlichen Energiesparplänen.

### Referenzliteratur

[141, FEDIOL, 2002]

#### **4.7.4.4 Wiederverwendung von Wärme bei der Härtung pflanzlicher Öle**

##### Beschreibung

Die Hydrogenierungsreaktion, die bei der Härtung von Ölen zur Herstellung von Fetten für das Kochen, den Verzehr und die Seifenherstellung stattfindet, ist ein exothermer Prozess. Die bei der Reaktion entstehende Wärmemenge beträgt 41,67 – 152,78 kWh/t (150 – 550 MJ/t) eingesetztes Material. Die erzeugte Wärme hängt vom Ausgangsmaterial den Produktvorgaben und dem Produkttyp ab; wenn beispielsweise weniger gehärtete Produkte erzeugt werden, wird auch weniger Dampf produziert. Diese Wärme wird eingesetzt, um das Produkt auf die gewünschte Reaktionstemperatur zu bringen und um später in der Reaktion Dampf zu erzeugen.

##### Erreichbare Umweltvorteile

Verringerter Energieverbrauch, z. B. Verbesserung der Prozesseffizienz durch Wärmerückgewinnung. Verringerung der Emissionen aus der Energieerzeugung.

##### Betriebsdaten

In einer Beispielraffinerie für Speiseöl wird der erzeugte Dampf in die bereits vorhandene Dampfhauptleitung der Anlage, die bei 350.000 Pa (3,5 bar) betrieben wird, eingespeist und verringert so den Primärdampfverbrauch der Anlage insgesamt. Die erreichbare Erzeugung von Energie (Dampf) beträgt den Angaben zufolge 25–125 kWh/t (90 – 450 MJ/t) (40 – 200 kg/t) nicht raffiniertes Öl. Außerdem lässt sich durch Nutzung der exothermen Energie aus der Härtung eine Senkung des Verbrauchs von Primärenergie am betreffenden Standort um 5 – 10 % erzielen.

##### Anwendbarkeit

In vielen Bereichen anwendbar und zuverlässig im Betrieb. Die Anwendbarkeit kann durch folgende Faktoren eingeschränkt werden:

- Anteil aller Produkte, die eine Härtung erfordern
- die bestehende Energieversorgungsstrategie der Anlage insgesamt, z. B. externe Versorgung
- der bestehende Energiemix der gesamten Anlage, z. B. das Verhältnis von Strom zu Dampf
- Art der Energieverträge mit externen Lieferanten/Verbrauchern.

##### Wirtschaftliche Aspekte

Zusätzliche Investitionen sind erforderlich. Geringere Betriebskosten durch geringere Dampferzeugung.

##### Anlass für die Umsetzung

Vorrausschauende Energieplanung.

##### Referenzliteratur

[65, Germany, 2002, 185, CIAA-FEDIOL, 2004]

#### **4.7.4.5 Mineralölwäscher zur Rückgewinnung von Hexan**

##### Beschreibung

Die Hexan- und Dampfbrüden aus der Desolventierung-Toastung des Schrots, der Miscella-Destillation, dem Auskocher und der Strippkolonne des Mineralölsystems werden durch einen Kondensator geleitet. Bestandteile, die vom Verdichter nicht kondensiert werden können, z. B. sehr geringe Mengen von Abluft mit Spuren von Hexan, werden von einem Mineralölwäscher absorbiert.

Der Mineralölwäscher besteht aus einer Absorptionssäule, in der das Hexan von kaltem Mineralöl mit Nahrungsmittelqualität (medizinisches Weißöl) absorbiert wird. Das mit Hexan befrachtete Mineralöl wird dann zwecks Rückgewinnung des Hexans durch eine Dampfstrippkolonne geleitet. Das Mineralöl wird abgekühlt und in der Absorptionssäule wiederverwendet.

Das Hexan und der Dampfbrüden aus der Dampfstrippkolonne werden im Kondensator kondensiert. Dann wird das Hexan-Wasser-Kondensat zum Hexan-Wasser-Abscheider geleitet. Das Abwasser wird im Hexan-Wasser-Abscheider dekantiert und das Hexan wieder zum Extraktionsprozess rückgeführt. Der Vorgang ist in Abbildung 4.57 dargestellt.

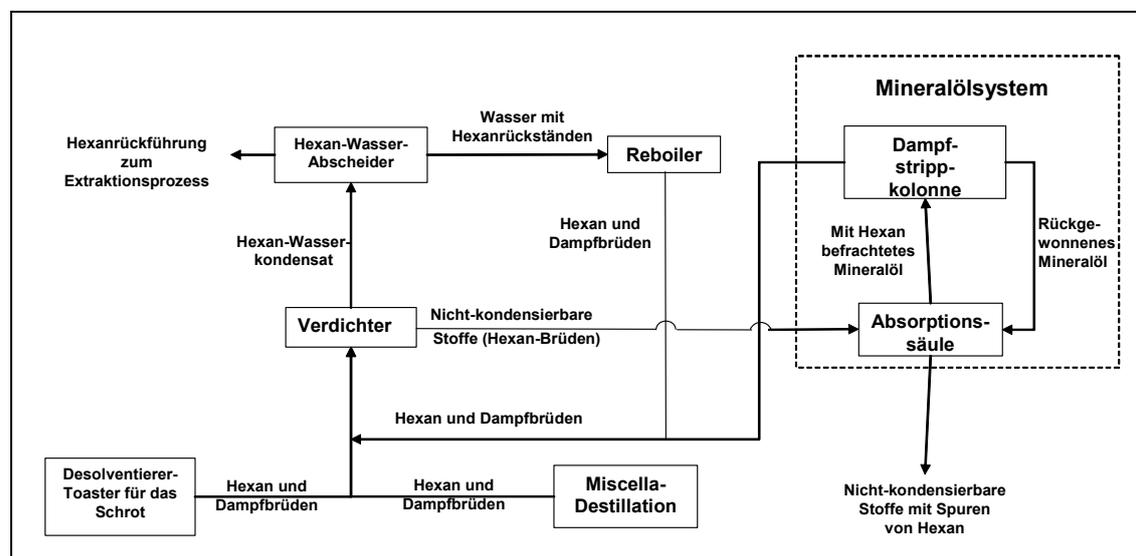


Abbildung 4.57: Mineralölsystem und zugehörige Prozessschritte  
[141, FEDIOL, 2002]

#### Erreichbare Umweltvorteile

Rückgewinnung von Hexan zur Wiederverwendung, dadurch geringere VOC-Emissionswerte.

#### Medienübergreifende Auswirkungen

Zusätzlicher Energieverbrauch, hauptsächlich durch die Erwärmung des Mineralöls unter Verwendung von Stripddampf und durch die Nutzung von Strom zum Pumpen des Öls.

#### Betriebsdaten

Hexan-Emissionskonzentrationen unter dem LEL (unterer Explosionsgrenzwert), z. B. etwa 40 g/m<sup>3</sup>, können erzielt werden. Der Energieverbrauch beträgt etwa 25 kg Dampf/Tonne Saat und 0,5 kWh/Tonne Saat.

#### Anwendbarkeit

Geeignet für bestehende und neue Anlagen, gute Betriebszuverlässigkeit und leicht verfügbar.

#### Wirtschaftliche Aspekte

Hohe Investitionskosten und zusätzliche Betriebskosten wegen des zusätzlichen Energieverbrauchs. Durch die Hexanrückgewinnung werden Kosten gespart.

#### Anlass für die Umsetzung

Größere Anlagensicherheit, Rückgewinnung und Wiederverwendung von Hexan, gesetzliche Auflagen zu VOC-Emissionen und die Tatsache, dass es keine bessere Alternative als Mineralöl mit Nahrungsmittelqualität zur Benutzung als Absorptionsflüssigkeit gibt.

#### Referenzliteratur

[141, FEDIOL, 2002]

4.7.4.6 Hexanrückgewinnung mit einem Auskocher und einem Schwerkraftabscheider

Beschreibung

Im Ölextraktionsprozess wird Hexan als Lösemittel eingesetzt. In der Folge kondensiert hexanreicher Brüden und bildet hexanhaltiges Prozesswasser mit Temperaturen von etwa 50 °C. Das ungelöste Hexan wird zum größten Teil mittels eines Leichtstoffabscheiders, also mit einem Hexan-Wasser-Abscheider, abgeschieden.

Etwaige Lösemittelrückstände in der wässrigen Phase des Hexan-Wasser-Abscheiders werden durch Erwärmung der wässrigen Phase auf etwa 80 – 95 °C im Auskocher abdestilliert. Die entstehenden Hexan-Wasser-Brüden des Auskochers werden zusammen mit den Brüden aus der Miscella-Destillation kondensiert. Die nicht kondensierbare gasförmige Materie der Brüden wird im Mineralölwäscher nach dem Kondensator behandelt, wobei Hexanrückstände absorbiert werden (siehe Abschnitt 4.7.4.5).

Sämtliches rückgewonnenes Hexan wird im Extraktionsprozess wiederverwendet. Nach dem Auskochen wird das fast hexanfreie Wasser in das Abwassersystem eingespeist. Mit dieser Technik werden auch mögliche Explosionsrisiken durch lösemittelreiches Abwasser im nachgeschalteten Abwasserbehandlungssystem beseitigt. Das Verfahren ist in Abbildung 4.58 dargestellt.

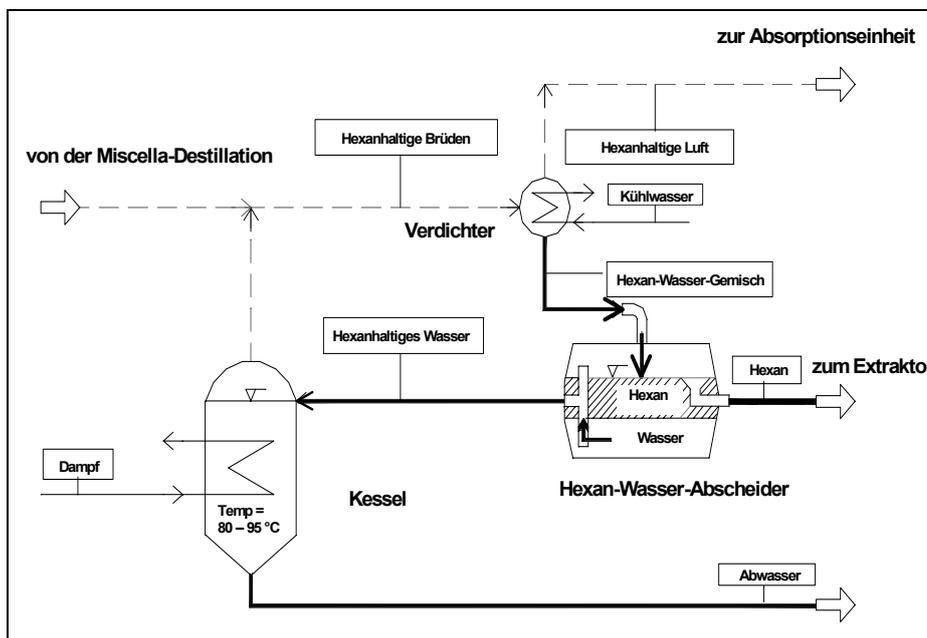


Abbildung 4.58: Verfahrensfliessbild für die Hexanrückgewinnung aus Prozesswasser bei der Extraktion nicht raffinierter pflanzlicher Öle

Erreichbare Umweltvorteile

Geringerer Verbrauch und geringere Hexan-Emissionen. Durch die Vermeidung explosiver Hexan-Luft-Gemische wird die Sicherheit des Abwassersystems gewährleistet. Minimierung von Lösemittelverlusten und des CSB/BSB im Abwasser.

Medienübergreifende Auswirkungen

Erhöhte Zufuhr von Wärmeenergie. Erhöhte Abwassertemperatur.

Betriebsdaten

Dampf wird mit einer Rate von 0,778 kWh/m<sup>3</sup> Wasser (1 kg/m<sup>3</sup>) verbraucht. Der Hexangehalt des Abwassers liegt unter 3 mg/l. Die Hexanrückgewinnung beträgt etwa 5 kg/t Saat.

Anwendbarkeit

Überall anwendbar und leicht verfügbar, ohne Einschränkungen. Durch Mehrstufigkeit, Temperaturregelung und -überwachung sehr zuverlässig im Betrieb.

Wirtschaftliche Aspekte

Geringere Kosten durch geringere Hexanverluste und höhere Kosten durch höhere Energiezufuhr.

Anlass für die Umsetzung

Gewährleistung der Anlagensicherheit, Einhaltung der örtlichen Abwassergrenzwerte für Kohlenwasserstoffe, Einhaltung von Lösemittelrückhalteverordnungen einschließlich der Gesetzgebung zur VOC-Vermeidung, also EG/99/13 und entsprechende nationale Gesetze.

Referenzliteratur

[65, Germany, 2002, 141, FEDIOL, 2002, 189, Bockisch M, 1993]

**4.7.4.7 Raffination pflanzlicher Öle**

Rohe Speiseöle enthalten verschiedene Arten unerwünschter Substanzen, z. B. 0,5 – 7,0 % freie Fettsäuren, Schleimstoffe (auch als Phosphatide, Phospholipide oder Lecithin bezeichnet), Spuren von Metallen, färbende Bestandteile und flüchtige Bestandteile. Die Beseitigung der freien Fettsäuren (<0,1 % freie Fettsäuren in raffiniertem Öl) kann entweder durch chemische oder durch physikalische Raffination erreicht werden.

**4.7.4.7.1 Chemische Raffination**Beschreibung

Die chemische Enthärtung umfasst die Zugabe von Natronlauge bei 75 – 110 °C, um die freien Fettsäuren zu verseifen, die Fällung der Seifen in der schweren wässrigen Phase und die Abscheidung der als Seifenstock bezeichneten schweren Phase durch Sedimentation oder Zentrifugation. Die Entfernung der nicht hydratisierbaren Schleimstoffe und Phosphatidsäuren kann in diesen Vorgang integriert werden, wenn ein ansäuernder Schritt vorangestellt, also Phosphor- oder Zitronensäure zugesetzt wird (siehe Beschreibung der Entschleimung in Abschnitt 2.2.4.2).

Der Seifenstock kann dann durch Aufspaltung zu sauren Ölen weiterverarbeitet oder an Dritte verkauft werden. In integrierten Anlagen besteht auch die Möglichkeit, ihn wieder in den Prozess zurückzuführen. Bei der Seifenspaltung werden die Fettsäureseifen zur Reaktion mit Schwefelsäure gebracht, damit sich erneut Fettsäuren bilden. Der Prozess kann kontinuierlich oder diskontinuierlich sein. Das Reaktionsmedium wird auf 70 – 100 °C erwärmt, um die Reaktion zu beschleunigen und die Trennung der oberen Ölphase von der unteren Wasserphase zu verbessern. Je nach Menge der noch im Rohöl vorhandenen Phosphatide kann sich zwischen der wässrigen Phase und den Fettsäuren eine Zwischenschicht aus Phosphatiden bilden. Die chemische Raffination von pflanzlichen Ölen ist in Abbildung 4.59 dargestellt.

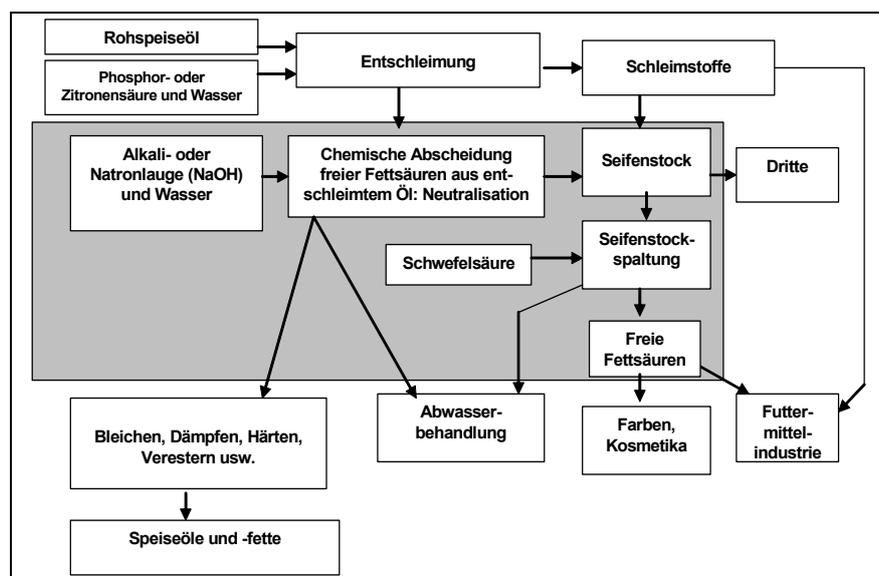


Abbildung 4.59: Grundfließbild für die chemische Raffination von pflanzlichen Ölen

Erreichbare Umweltvorteile

Entfernung und Rückgewinnung freier Fettsäuren. Hohes Potenzial für Rückgewinnung und Verbesserung von Nebenprodukten als Tierfutter oder für technische Anwendungen in anderen Branchen. Weniger Zusatz von Bleicherde.

Medienübergreifende Auswirkungen

Die Abwasserbehandlung wird komplizierter, da eine erhöhte P-Fracht bei der Seifenspaltung anfällt, wenn Phosphorsäure zur Entschleimung eingesetzt wird und sich die CSB/BSB-Fracht und die Schwefelfracht bei der Seifenspaltung erhöht. Erhöhung der BSB/CSB-Fracht bei Einsatz von Zitronensäure zur Entschleimung<sup>32</sup>.

Betriebsdaten

Angaben zufolge hängt der Chemikalienverbrauch von der Zusammensetzung des Rohstoffs ab, zudem lässt er sich durch das mechanische Durchmischen von Chemikalien und Ölen/Fetten verringern. So haben beispielsweise die meisten Rohöle einen Gehalt an freien Fettsäuren zwischen 0,5 und 3,0 %. Rohes Palmöl, Palmkernöl, Olivenöl und Kokosöl haben einen Gehalt an freien Fettsäuren von bis zu 7 % und die Verbrauchsangaben sind entsprechend höher.

Tabelle 4.98 zeigt Verbrauchs- und Emissionswerte für die chemische Raffination von pflanzlichen Ölen.

| Parameter   | Allgemeine Daten  | Deutsches Beispiel                                 |
|---|---|--|
| Natronlauge (100 %) zur Neutralisation.<br>Menge vom Gehalt an freien Fettsäuren abhängig (maximal 3 %)   | 1 – 6 kg/t Öl   |  |
| Dampf zur Neutralisation und Seifenspaltung. Menge hängt von Phosphatid- und Wassergehalt ab  | 117 kWh/t Seife (150 kg/t)<br>Für Entfernung freier Fettsäuren      | 117 kWh/t nicht raffiniertes Öl (150 kg/t)         |
|   | 156 – 778 kWh/t Seife (200 – 1000 kg/t Seife)<br>Für Seifenspaltung |  |
| Phosphorsäure (75 %) zur Entschleimung*.<br>Menge hängt vom Phosphatidgehalt ab   | 0,8 – 5 kg H <sub>3</sub> PO <sub>4</sub> /t Öl                     |  |
| Schwefelsäure (96 %) für die Seifenspaltung**.<br>Menge abhängig vom Gehalt an Natronlauge  | 100 – 250 kg/t Seife  | 50 – 250 kg/t Seife                                |
| Wasser zum Waschen des Öls  | 50 – 300 l/t Seife  | 200 kg/t nicht raffiniertes Öl                     |
| Elektrizität  | 5 – 15 kWh/t Öl (18 – 54 MJ/t)                                      |  |
| <b>Abwasser</b>   |   |  |
| Volumen   |   | bis zu 0,3 m <sup>3</sup> /t nicht raffiniertes Öl |
| CSB   |   | bis zu 15.000 mg/l                                 |
| Sulfat  |   | bis zu 15.000 mg/l                                 |
| Organischer Phosphor  |   | bis zu 2.000 mg/l                                  |
| * Wenn statt der Phosphorsäure Zitronensäure verwendet wird, besteht eventuell ein Risiko der Vergiftung des Katalysators (Ni) für die Härtung durch Spuren von Zitronensäure, sodass die Durchsatzrate der nachgeschalteten Prozesse sinkt |   |  |
| **Um den Sulfatgehalt im Abwasser zu verringern, muss die Schwefelsäure bei der Seifenspaltung optimal dosiert werden   |   |  |

**Tabelle 4.98: Verbrauchs- und Emissionswerte für die chemische Raffination von pflanzlichen Ölen**

<sup>32</sup> Anm. d. UBA-Bearb.: Mit Einsatz der Zitronensäure wird aber die P-Fracht insgesamt reduziert. Daher wird in D zunehmend Zitronensäure eingesetzt (s. Kap. 4.7.4.8).

Anwendbarkeit

Geeignet für neue und bereits bestehende Anlagen. Diese Technik ist für Rohöl mit einem geringen Gehalt an freien Fettsäuren, also <3 %, geeignet. Die Technik ist leicht verfügbar und bietet bei einem breiten Spektrum von Rohstoffen und Produkten eine hohe Zuverlässigkeit.

Wirtschaftliche Aspekte

Das hohe Potenzial für die Nebenproduktrückgewinnung bedeutet eine Kostenersparnis. In Verbindung mit der Bereitstellung von Geräten für Handhabung und Behandlung des Sauerwassers und mit dem Betrieb fallen Kosten an.

Anlass für die Umsetzung

Bessere Produktqualität, also geringerer Gehalt an freien Fettsäuren, längere Haltbarkeitsdauer und höhere Zuverlässigkeit des Verfahrens. Die Technik ist für eine breite Palette von Rohstoffen und Produkten geeignet.

Referenzliteratur

[65, Germany, 2002, 141, FEDIOL, 2002]

**4.7.4.7.2 Physikalische Raffination**Beschreibung

Alle im Öl vorliegenden freien Fettsäuren können durch Destillation in einem Desodorierer (Dämpfer) entfernt werden. Mit einer physikalische Vorbehandlung kann durch Entschleimung und den Einsatz von Bleicherde ein niedriger Phospholipidgehalt erzielt werden. Die freien Fettsäuren können dann aus dem physikalisch vorbehandelten Öl mittels Dampf unter Vakuum bei Temperaturen von rund 250 °C ausgetrieben werden. Die in Kap. 4.7.4.7.1 beschriebenen Entsäuerungsprozesse können übersprungen werden, da hier die Entsäuerung und Desodorierung (Dämpfung) kombiniert und in einem kontinuierlich arbeitenden Gerät mit einer oder mehreren Stufen mit integrierten Wärmetauschern und injiziertem Strippungsdampf erfolgt. Im direkten Anschluss folgt ein Wäscher zum Kondensieren des größten Teils des Fetts aus dem Brüden als wasserfreies Produkt. Dieser Schritt wird im Allgemeinen durchgeführt, hängt aber vom Rohmaterial und den Produkten ab sowie davon, dass das eingehende Öl viele freie Fettsäuren und wenig Phospholipide enthält. Das nach dem Desodorierer angeordnete Wäschersystem muss eine viel größere Menge freier Fettsäuren entfernen als bei der Dämpfung der chemischen Raffination.

Erreichbare Umweltvorteile

Rückgewinnung hochkonzentrierter freier Fettsäuren. Weniger Chemikalienverbrauch, da der chemische Neutralisationsschritt ausfällt, also keine Natronlauge oder Schwefelsäure benötigt werden. Es ist keine Seifenspaltung bei reinen Raffineriebetrieben erforderlich. Bei der physikalischen Raffination ist die Ölausbeute höher, wird weniger Wasser verbraucht und entsteht weniger Abwasser. Geringere Fett-, Sulfat- und Phosphat-Frachten im Abwasser.

Medienübergreifende Auswirkungen

Der Bleicherdeverbrauch ist bis zu viermal höher als bei der chemischen Ölraffination. Es wird mehr Strippdampf verbraucht als bei der chemischen Raffination.

Betriebsdaten

Es können hochkonzentrierte freie Fettsäuren (bis zu 85 %) rückgewonnen werden. Der angegebene Dampfverbrauch beträgt 116,7 – 311 kWh/t Öl (150 – 400 kg/t), der Stromverbrauch 15 – 40 kWh/t Öl (54 – 144 MJ/t).

Anwendbarkeit

Geeignet für neue Anlagen. Diese Technik ist für Rohöl mit hohem Gehalt an freien Fettsäuren, also mehr als 2 %, und geringem Gehalt an Phospholipiden vor dem Dämpfen, also etwa 10 ppm oder weniger, geeignet. Die Technik ist leicht verfügbar und arbeitet sehr zuverlässig.

Wirtschaftliche Aspekte

Im Vergleich zur chemischen Raffination entfallen die Kosten für den chemischen Neutralisationsschritt; es fallen geringere Arbeitskosten an, da keine Seifenspaltung erfolgt, sowie geringere Abwasserbehandlungs-

kosten, weil die Wasserverschmutzung geringer ist, und höhere Kosten für den höheren Bleicherdeverbrauch. Höhere Raffinerieausbeute als bei der chemischen Raffination.

Anlass für die Umsetzung

Höhere Ausbeuten, geringere Umweltbelastung, kein saures Wasser.

Referenzliteratur

[65, Germany, 2002, 141, FEDIOL, 2002]

**4.7.4.8 Verwendung von Zitronensäure an Stelle von Phosphorsäure für die Ölentseimung**

Beschreibung

Für die Entseimung, also die Entfernung von Phosphatiden/Phospholipiden/Lecithinen au rohen Öl, kann an Stelle von Phosphorsäure auch Zitronensäure verwendet werden.

Die Entseimung kann getrennt durchgeführt oder mit der chemischen Raffination integriert werden, also im Entsäuerungsschritt erfolgen (siehe Abschnitt 4.7.4.7.1). Entseimtes Öl, also mit <30 ppm P im Öl, kann auch zur weiteren Verarbeitung in physikalischen Raffinationsprozessen verwendet werden (siehe Abschnitt 4.7.4.7.2).

Die Schleimstoffe der freien Fettsäuren sind entweder hydratisierbar oder nicht hydratisierbar. Die hydratisierbaren Schleimstoffe können nach Mischen mit Wasser in einer Zentrifuge vom Öl abgetrennt und dem Schrot einer integrierten Ölsa-Extraktionsanlage zugegeben werden. Sie lassen sich auch weiter verarbeiten, um Lecithin mit Nahrungsmittelqualität zu erhalten, oder als Rohstoff für Tierfutter verwendet werden.

Wenn die nicht hydratisierbaren Schleimstoffe und Phosphatidsäuren zuerst angesäuert werden, können sie anschließend durch Zugabe von Wasser und nachfolgende Zentrifugation vom Rohöl getrennt werden. Dieser Prozess wird auch als Säureentseimung bezeichnet. Der Markt verlangt, dass der Phosphorgehalt im raffinierten Öl unter 5 ppm liegt. Phosphor im Abwasser ist durch die Phosphorsäurerückstände und das Vorhandensein organisch gebundenen Phosphors in Form von Phosphatiden unvermeidlich. Angaben zufolge lassen sich die Phosphatide nicht durch eine Vorfällung aus dem Abwasser beseitigen. Wenn die Ansäuerung mit Zitronensäure an Stelle von Phosphorsäure durchgeführt wird, lässt sich die P-Fracht des Abwassers reduzieren. Die auf dem Phosphatidgehalt im Rohöl beruhende P-Fracht wird durch den Einsatz von Zitronensäure nicht gesenkt. Zitronensäure erhöht jedoch den CSB und den BSB des Abwassers. Abbildung 4.60 zeigt ein Grundfließbild für die Säureentseimung.

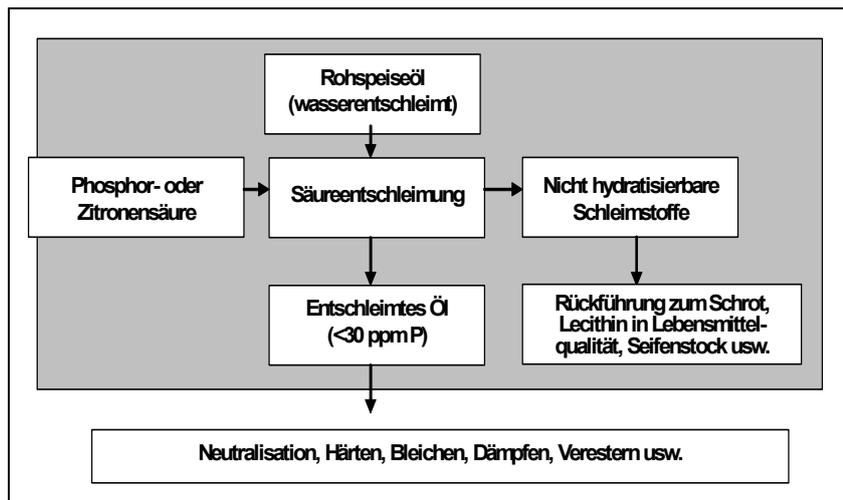


Abbildung 4.60: Grundfließbild für die Säureentseimung von pflanzlichem Öl

Erreichbare Umweltvorteile

Phosphatide lassen sich weiter raffinieren und ergeben dann Lecithin in Lebensmittelqualität als Koprodukt, oder sie können dem Schrot einer integrierten Anlage wieder zugeführt werden, also Wiederverwendung eines

Nebenprodukts. Verringerung der Phosphorfracht im Abwasser. Geringer Rückgang der Abwasserschlammmenge.

#### Medienübergreifende Auswirkungen

Höherer CSB und BSB im Abwasser.

#### Betriebsdaten

Je nach Produktpalette wird eine Reduzierung der Phosphorfracht des Abwassers um mehr als 50 % angegeben. Es wird auch berichtet, dass die Verwendung von 1 kg Zitronensäure zu einem CSB von 0,75 kg im Abwasser führt. Der Verbrauch an Zitronensäure ist erheblich höher als der Verbrauch an Phosphorsäure. Die Benutzung von Zitronensäure kann zu Problemen bei der Entschleimung von bestimmten Arten von Rohöl führen, die einen hohen Phosphatidgehalt haben.

Angaben zufolge erfolgt das Abscheiden von hydratisierbaren Phospholipiden bei einer Temperatur von 60 – 70 °C. Dagegen erfordert die Beseitigung nicht hydratisierbarer Phospholipide höhere Temperaturen, z. B. 75 – 110 °C.

#### Anwendbarkeit

Die Technik ist überall anwendbar und geeignet für neue und bestehende Anlagen. Durch den Einsatz von Zitronensäure an Stelle von Phosphorsäure wird möglicherweise die Durchsatzrate der nachfolgenden Prozesse gesenkt. Außerdem können Zitronensäurerückstände den Ni-Katalysator während des Härtingsprozesses vergiften, wenn das Öl zur Margarineherstellung verwendet wird, sodass hiervon die Wahl der Säure für die Entschleimung beeinflusst werden kann. Die Technik ist leicht verfügbar und arbeitet sehr zuverlässig.

#### Wirtschaftliche Aspekte

Geringere Kosten für die Abwasserbehandlung. Höhere Kosten für Chemikalien. Für eine angemessene Entschleimung des Rohöls ist fünfmal mehr Zitronensäure als Phosphorsäure erforderlich. Zitronensäure hat ein höheres Molekulargewicht und ist eine schwächere Säure. Die Nebenprodukte haben einen Verkaufswert.

#### Anlass für die Umsetzung

Strengere Vorschriften für die Abwasserqualität. Der Wert der Nebenprodukte, z. B. von Phospholipiden, kann die Entscheidung für die separate Entschleimung oder die integrierte Entschleimung und Entfernung von freien Fettsäuren beeinflussen.

#### Referenzliteratur

[65, Germany, 2002, 141, FEDIOL, 2002, 189, Bockisch M, 1993]

### **4.7.4.9 Enzymatische Entschleimung**

#### Beschreibung

Die physikalische Raffination (siehe Abschnitt 4.7.4.7.2) bietet geringere Kosten, höhere Ausbeuten und weniger Chemikalieneinsatz bei der Raffination pflanzlicher Rohöle. Eine Voraussetzung für die physikalische Raffination ist ein geringer Phosphatidgehalt im Öl, wenn es in den letzten Desodorierungsschritt (Dämpfungsschritt) eintritt. Der Gehalt an Phosphatiden wird bei der Entschleimung reduziert. Die Entschleimung kann durch die enzymatische Hydrolyse der Phosphatide erfolgen. Das Enzym Phospholipase-A<sub>2</sub> katalysiert die Spaltung des Fettsäureesters unter milden Bedingungen. Das flüssige Enzym wird bei 60 °C und pH 5 in das Öl dispergiert, wobei Zitronensäure und Natronlauge als ein Natriumcitratpuffer fungieren. Um die geringe Reaktionsrate der enzymatischen Reaktion zu erhöhen, wird eine ganze Reihe kontinuierlich durchmischter Reaktoren eingesetzt. Das entstehende Lysolecithin-Molekül ist wasserlöslich und kann durch Zentrifugation abgetrennt werden.

#### Erreichbare Umweltvorteile

Weniger Verbrauch von Natronlauge, Phosphor- und Schwefelsäure, Wasser und Energie.

#### Betriebsdaten

In einer Beispielanlage wurden nach Produktionsbeginn Verfahrensprobleme beobachtet. Die Emissionsgrenzwerte wurden innerhalb von 3 Monaten erreicht. Die Kosten wurden durch Verbesserung der Eigenschaften der Phospholipase erheblich gesenkt.

In einer Beispielanlage entsteht mit der konventionellen Methode ein Abwasserstrom von etwa 3.200 kg/h, der auch Sulfat und Phosphat enthält. Im Vergleich dazu fallen beim enzymatischen Verfahren etwa 400 kg/h an. Außerdem wird das Schlammauftreten etwa um den Faktor 8 reduziert. Verbrauchszahlen für die konventionelle und die enzymatische Entschleimung werden in Tabelle 4.99 verglichen.

| Ressource            | Einheit        | Verbrauch<br>(Einheiten/t Rohöl) |                               |
|----------------------|----------------|----------------------------------|-------------------------------|
|                      |                | Konventionelles<br>Verfahren     | Enzymatische<br>Entschleimung |
| Natronlauge (100 %)  | kg             | 5,3                              | 0,43                          |
| Phosphorsäure (75 %) | kg             | 2,0                              |                               |
| Schwefelsäure (96 %) | kg             | 5,3                              |                               |
| Zitronensäure        | kg             |                                  | 1,0                           |
| Weiches Wasser       | kg             | 127,8                            | 10,76                         |
| Kühlwasser           | m <sup>3</sup> | 1,5                              |                               |
| Strom                | kWh            | 7,7                              | 7                             |
|                      | MJ             | 28                               | 25                            |
| Dampf                | kWh            | 75                               | 22                            |
|                      | MJ             | 270                              | 80                            |
|                      | kg             | 95,5                             | 28                            |
| Enzymlösung          | kg             |                                  | 0,014                         |

**Tabelle 4.99: Verbrauchszahlen für die konventionelle und die enzymatische Entschleimung von pflanzlichem Öl [35, OECD, 2001, 182, Germany, 2003]**

Anwendbarkeit

Kann bei allen Arten von Raps- und Sojabohnenöl angewendet werden.

Wirtschaftliche Aspekte

Die Kosten für die konventionelle und die enzymatische Entschleimung werden in Tabelle 4.100 verglichen.

| Ressource            | Spezifische<br>Kosten<br>(USD/Einheit) | Gesamtkosten                |   |
|----------------------|--|-----------------------------|---|
|                      |  | Konventionell<br>(USD/t Öl) | Enzymatische<br>Entschleimung<br>(USD/t Öl) |
| Natronlauge (100 %)  | 0,6/kg                                 | 3,18                        | 0,26  |
| Phosphorsäure (75 %) | 0,672/kg                               | 1,34                        |   |
| Schwefelsäure (96 %) | 0,075/kg                               | 0,39                        |   |
| Weiches Wasser       | 0,013/kg                               | 1,66                        | 0,14  |
| Dampf                | 0,01 – 0,09/kg <sup>3*</sup>           | 1,24                        | 0,36  |
| Kühlwasser           | 0,09/m <sup>3</sup>                    | 0,69                        |   |
| Strom                | 0,09/kWh                               | 0,69                        | 0,63  |
| Zitronensäure        | 1,87/kg                                |                             | 1,87  |
| Enzymlösung          | 143,75/kg                              |                             | 2,01  |
| Gesamt               | 147.173                                | 9,19                        | 5,27  |

\* Differenz durch unterschiedlichen Dampfdruck

**Tabelle 4.100: Kosten für die konventionelle und die enzymatische Entschleimung von pflanzlichem Öl [35, OECD, 2001]**

Anlässe für die Umsetzung

Geringere Kosten.

Beispielanlagen

Die Technik wird in mindestens einer Anlage in Deutschland eingesetzt, in der Öl aus Saaten gewonnen, Öl raffiniert und raffiniertes Öl in Flaschen abgefüllt und verpackt wird.

Referenzliteratur

[35, OECD, 2001]

#### 4.7.4.10 Einsatz von Zyklonen zur Verringerung der Nassstaubemissionen bei der Extraktion pflanzlicher Öle

##### Beschreibung

Nach der Desolventierung und Toastung kommen die Flocken aus der Ölgewinnung in einen Trockner, in dem überschüssige Feuchtigkeit durch erwärmte Umgebungsluft entzogen wird, und anschließend in einen Kühler, in dem die Temperatur des getrockneten Schrots mit Umgebungsluft abgesenkt wird. Die Abluft von Trocknung und Kühlung enthält Staub. Durch die relativ hohe Luftfeuchtigkeit der Abluft aus der Trocknungsstufe ist der Staub feucht und klebrig und besonders schwer aufzufangen. Der Staub wird mit Zyklonen entfernt und dann dem getrockneten Schrot wieder zugeführt, das z. B. als Tierfutter verwendet werden kann. Abbildung 4.61 zeigt ein Grundfließbild der Nassstaubemissionsabscheidung durch Zyklone.

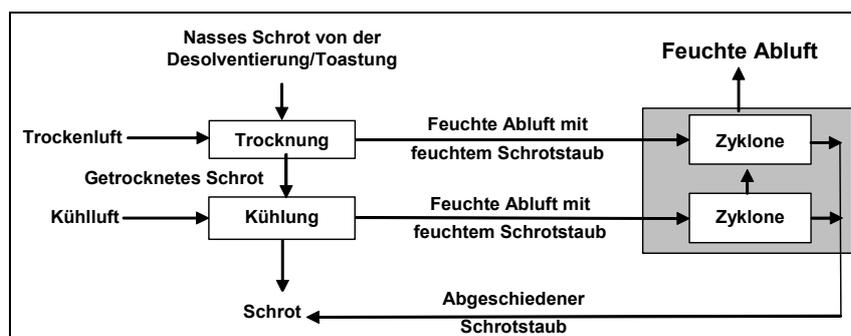


Abbildung 4.61: Grundfließbild der Nassstaubemissionsabscheidung durch Zyklone

##### Erreichbare Umweltvorteile

Geringere Staubemissionen, rückgewonnenes Produkt und geringeres Brandrisiko.

##### Medienübergreifende Auswirkungen

Strom wird verbraucht, um den Druckverlust in den Zyklonen zu überwinden.

##### Betriebsdaten

Zyklone werden aus praktischen und aus Sicherheitsgründen verwendet.

Der Einsatz von Gewebefiltersystem würde zu einer Kondensation der Feuchtigkeit führen, die wiederum die Ablagerung von Staub und Verstopfung von Leitungen verursachen würde. Die Kombination aus heißer Trocknungsluft und abgelagertem Schrotstaub kann schließlich zur Selbstentzündung des Staubs und zu einem Brand führen. Solche Brände stellen aufgrund der Nähe der Hexan-nassen Flocken in der vorangehenden Desolventier-Toaster-Anlage eine besonders gefährliche Situation dar.

Auch elektrostatische Abscheider führen durch die Funkenbildung in Kombination mit den hohen Hexankonzentrationen in der Abluft zu einem Brand- und Explosionsrisiko. Die feinen, feuchten und klebrigen Schrotpartikel neigen dazu, sich zusammenzuballen, sodass der Anteil der feinen Partikel in der Abluft relativ gering ist. Deswegen sind diese Abscheider, die eigentlich für die Beseitigung feiner Partikel ausgelegt sind, nicht geeignet. Außerdem würden die getrockneten Schrotpartikel in einem Wäscher nass werden, und das aufgefangene Schrot müsste erneut getrocknet werden.

Für den Einsatz von Zyklonen wird eine gute Betriebszuverlässigkeit und Verfügbarkeit angegeben. Es werden Nassstaub-Emissionskonzentrationen von  $< 50 \text{ mg/Nm}^3$  erzielt.

##### Anwendbarkeit

In neuen und bereits bestehenden Anlagen anwendbar.

##### Wirtschaftliche Aspekte

Investitionskosten fallen für die Zyklone und die Transportsysteme für das rückgewonnene Schrot an. Die Betriebskosten sind hoch, z. B. durch den zusätzlichen Energieverbrauch.

##### Anlass für die Umsetzung

Weniger Produktverluste und Feuervermeidung. Die Technik ist Angaben zufolge technisch und verfahrensmäßig gut.

### Referenzliteratur

[141, FEDIOL, 2002]

#### **4.7.4.11 Wasserringpumpen zur Erzeugung eines zusätzlichen Vakuums von 40 – 120 mbar**

##### Beschreibung

Wasserringpumpen erzeugen ein niedriges, stabiles Vakuum, das zum Entgasen und für das Trocknen von Ölen und Fetten tierischer und pflanzlicher Herkunft verwendet werden kann. Beim Entgasen des Öls wird das Vakuum während der Härtung, für die  $H_2$  verwendet wird, und nach der Veresterung eingesetzt, bei der Wasser zur Inaktivierung des Katalysators zum Einsatz kommt. Beim Trocknen des Öls wird das Vakuum nach der Entschleimung, nach der Neutralisation, vor und nach der Veresterung und vor der Härtung eingesetzt. Das Vakuum wird auch genutzt, um eine sauerstofffreie Atmosphäre im Reaktor/Evakuierung des Reaktors während der Härtung und Veresterung sicherzustellen.

##### Erreichbare Umweltvorteile

Geringerer Energiebedarf. Geringe Verschmutzung des Abwassers. Geringere Emissionen aus der Energieerzeugung.

##### Medienübergreifende Auswirkungen

Erzeugung von Abwasser.

##### Betriebsdaten

Abwasser entsteht durch das Wasser, das zum Pumpenantrieb (Wasserring) genutzt wird. Es weist im Allgemeinen ein geringes spezifisches Volumen pro Einheit auf. Bedingt durch die Anwendungen, wird dieses Wasser in der Pumpe nur geringfügig verschmutzt, selbst wenn es Kondensate aus dem Trocknungsprozess enthält. Die Fracht lässt sich anhand ihres CSB beschreiben, da unter den vorherrschenden Prozessbedingungen, nämlich Temperaturen von  $\leq 100$  °C, Stickstoff- und Phosphorverbindungen nicht in das Wasser gelangen können. Als Abwasservolumen werden bis zu  $1,7 \text{ m}^3/\text{t}$  nicht raffiniertes Öl angegeben, und der CSB kann bis zu  $75 \text{ mg/l}$  betragen.

##### Anwendbarkeit

Anwendbar, wenn ein Vakuum zwischen 40 und 120 mbar erforderlich ist. Die Technik ist leicht verfügbar und die Betriebszuverlässigkeit ist sehr gut. Die Pumpen werden in Serienproduktion hergestellt. Die Technik führt zu einem geringen Abluftdurchsatz.

##### Wirtschaftliche Aspekte

Geringere Kosten durch angepasste Vakuumbedingungen.

##### Anlass für die Umsetzung

Vielfalt der betroffenen Systeme. Vollkommen andere Vakuumbedingungen als für die destillative Entsäuerung/Desodorierung (Dämpfung).

### Referenzliteratur

[65, Germany, 2002, 189, Bockisch M, 1993]

#### **4.7.4.12 Desodorierung (Dämpfung)**

Die Desodorierung oder Dämpfung ist der letzte Behandlungsschritt im Raffinationsprozess, bei dem Rohöl in fertiges Öl umgewandelt wird. Das vorbehandelte Öl wird mit einem Wärmetauscher und indirektem Dampf auf die Desodorierungstemperatur, d. h.  $180 - 270$  °C, erwärmt. Um eine Oxidation des Öls zu vermeiden, herrscht im Dämpfungsgerät ein fast absolutes Vakuum, nämlich  $0,5 - 8$  mbar. Bei den gegebenen Vakuum- und Temperaturbedingungen liefert Strippdampf den Antrieb und das Trägermaterial für die Entfernung flüchtiger Bestandteile aus dem Ausgangsmaterial.

Die Brüden aus dem Dämpfungsapparat enthalten Luft, Wasserdampf, Fettsäuren und andere flüchtige Substanzen. Vor dem Eintritt in das Vakuumgerät passieren die Brüden einen Wäscher. Eine Waschflüssigkeit wird in den Brüdenstrom gesprüht. Fettsäuren und flüchtige Substanzen kondensieren teilweise an den Wasch-

substanz-Tröpfchen oder aber am Packmaterial. Da der Wäscher an dasselbe niedrige Vakuum wie der Dämpfer angeschlossen ist, kondensiert der Wasserdampf nicht.

Der vorgereinigte Brüdenstrom tritt jetzt in den Booster (Dampfstrahl-Vakuumpumpe) des mehrstufigen Vakuumsystems ein. Der Dampfstrahl ist ein Thermokompressor, sodass der Dampfdruck um bis zu 30 – 50 mbar ansteigt. In einem klassisch ausgelegten Vakuumsystem werden die Brüden dann in einem offenen barometrischen Kondensator verdichtet. Der Strippdampf und der für die Booster erforderliche Treibdampf werden verdichtet. So wird eine außerordentliche Volumenreduktion erzielt. Dies trägt dazu bei, das Vakuum auf dem vorgegebenen Niveau zu halten. Nicht-kondensierbare Bestandteile aus dem barometrischen Hauptkondensator werden durch ein Entlüftungssystem entfernt, das aus mehreren kleinen Zwischenkondensatoren und einem oder mehreren Boostern besteht. Die Verdichter arbeiten auch mit Kühlwasser, d. h. etwa 10 – 15 % des Kühlwassers fließen durch den Hauptkondensator. Das Wasser aus den barometrischen Kondensatoren kann verunreinigt sein. Die Funktion von 1 oder 2 Dampfstrahlern kann durch den Einsatz einer Wasserringpumpe ersetzt werden (siehe Abschnitt 4.7.4.11).

In den Abschnitten 4.7.4.12.1 – 4.7.4.12.3 werden einige für die Dämpfung eingesetzte Techniken beschrieben. Tabelle 4.101 zeigt einen Vergleich der Kühlsysteme, die zur Vakuumerzeugung bei der Desodorierung/Dämpfung von pflanzlichen Ölen eingesetzt werden, basierend auf einem moderaten Vakuum von etwa 4 mbar.

| Kühlsysteme zur Vakuumerzeugung  | Dampf | Elektrizität | Gesamtzufuhr Primärenergie | Abwasser | Investitionskosten | Komplexität des Systems |
|----------------------------------|-------|--------------|----------------------------|----------|--------------------|-------------------------|
| Durchlaufsystem                  | –     | ++           | ++                         | --       | ++                 | ++                      |
| Alkalischer Kreislauf            | --    | +            | -/+                        | –        | +                  | +                       |
| Alkalischer Kreislauf mit Kühler | +     | –            | –                          | +        | –                  | –                       |
| Trockene Kondensation            | ++    | --           | –                          | ++       | --                 | --                      |

+ (++) = (am) günstig(sten)  
 - (--) = (am) ungünstig(sten)  
 Anmerkung: Die Gesamtzufuhr der Primärenergie für das jeweilige Vakuumsystem ist die Summe der Energie, die in der Anlage zur Erzeugung von Dampf benötigt wird, und der Energiezufuhr im externen Kraftwerk, die zur Erzeugung des benötigten Stroms verwendet wird.

**Tabelle 4.101: Vergleich der Kühlsysteme, die zur Vakuumerzeugung bei der Desodorierung von pflanzlichen Ölen benutzt werden**  
 [141, FEDIOL, 2002]

#### 4.7.4.12.1 Doppelwäscher in Kombination mit einem Durchlaufkühlsystem bei der Desodorierung von pflanzlichen Ölen

##### Beschreibung

Die Desodorierungs-Brüden werden in einem Wäscher behandelt. Der vorgereinigte Brüdenstrom wird mit dem Treibdampf der Booster-Dampfstrahler gemischt. Die Installation eines zweiten Wäschers zwischen einem Booster-Dampfstrahler und dem Hauptkondensator ermöglicht eine weitere Kondensation flüchtiger Stoffe, was zu einer Reinigung von Stripp- und Treibdampf vor der Vermischung mit Kühlwasser des Hauptkondensators in einem Durchlaufkühlsystem führt. Der zweite Wäscher kann über festes Packmaterial oder über eine eigene Wäscherschleife mit einem Kühler zur Beseitigung der Kondensationswärme und einen nachgeschalteten Nebelabscheider verfügen. Der zweite Wäscher arbeitet mit höherem Druck, und durch die Zugabe von Dampf über den Booster-Dampfstrahl wird der Partialdruck der flüchtigen Stoffe verringert. Diese zwei Faktoren liefern die Basis für die weitere Verdichtung.

Durch die doppelte Wäscheranordnung erhöht sich die Wascheffizienz für die Dämpfungs-Brüden. Die zusätzliche Kondensation flüchtiger Bestandteile im zweiten Wäscher reduziert den organischen Massenstrom im Hauptkondensator. Gleichzeitig bedeutet der zweite Wäscher einen zusätzlichen Wärmeverlust; der Gesamtenergiebedarf des Systems ist jedoch gering.

Das Kühlwasser ist Oberflächenwasser, das nach Passieren eines Fettabscheiders wieder an die Umwelt abgegeben wird. Lipophile Stoffe finden sich im Kühlwasser in nur sehr geringer Konzentration. Zudem verringert der Einsatz des zweiten Wäschers die gesamte organische Verschmutzungsfracht des Kühlwassers und verbessert das Umweltprofil des Kühlsystems.

Abbildung 4.62 zeigt ein einfaches Flussdiagramm des Prozesses.

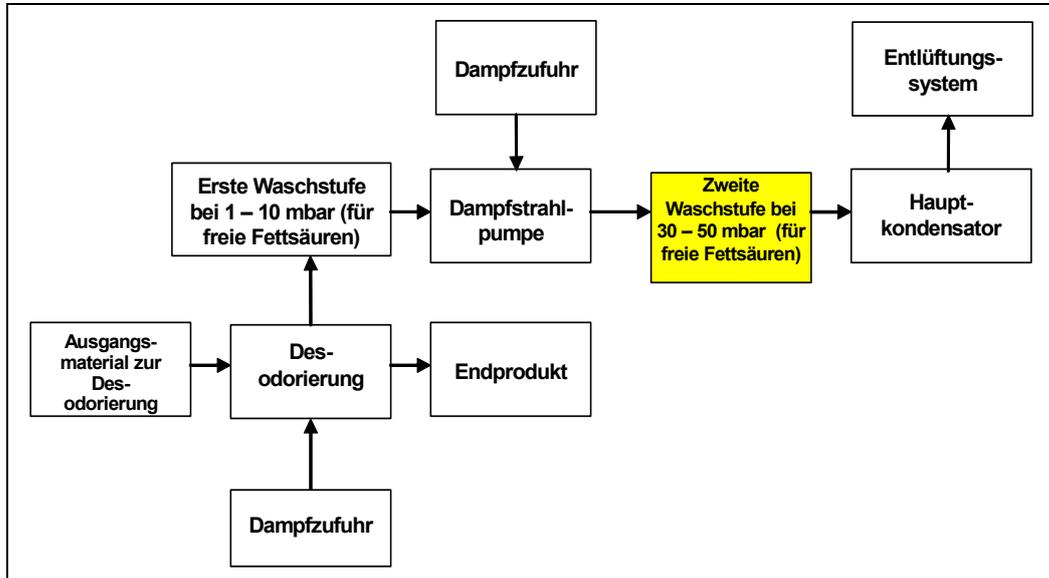


Abbildung 4.62: Grundfließbild der Doppelwäscheranordnung bei der Desodorierung

Erreichbare Umweltvorteile

Geringer Energiebedarf des Vakuumsystems. Verringerung der CSB-Fracht. Im Vergleich zu dem System mit einem Wäscher und Durchlaufkühlung werden mehr Nebenprodukte rückgewonnen.

Medienübergreifende Auswirkungen

Stromverbrauch für die zweite Wäscherstufe.

Betriebsdaten

Die Wascheffizienz des ersten Wäschers liegt bei chemisch vorraffiniertem Rohöl deutlich über 90 %. Mit diesem Behandlungsschritt wird der größte Teil der Fettsäuren entfernt. Der zweite Wäscher erhöht die Gesamtwascheffizienz um weitere 2 – 5 %. Die Wäschereffizienz hängt vom Gehalt an freien Fettsäuren im Ausgangsmaterial für die Desodorierung ab.

Angaben zufolge werden in der Doppelwäscheranordnung in Kombination mit einem Durchlaufkühlsystem keine Wärmetauscher am Hauptkondensator eingesetzt. Deshalb gibt es auch keine Probleme mit Belagbildung im Wärmetauscher oder mit schlechtem Wärmeaustausch. Durch die einfache Systemgestaltung ist der Prozess sehr stabil.

Da das Kühl-/Vakuumsystem auf Dampfstrahlpumpen und offenen Kondensatoren mit direktem Kühlwasser beruht, hat es den geringsten Energiebedarf für die Erzeugung des gewünschten Vakuums hinsichtlich Strom- und Dampfverbrauch. Das System produziert jedoch einen Kühlwasserstrom mit erhöhtem CSB. Die Zunahme des CSB kann zwischen 50 und 150 mg/l schwanken, je nach Kühlwasserdurchfluss und Qualität des Ausgangsmaterials für die Desodorierung. Die Doppelwäscheranordnung führt zu einer verringerten CSB-Belastung, nämlich 40 – 100 mg/l. Als Abwasservolumen werden 1 – 10 m<sup>3</sup>/t nicht raffiniertes Öl angegeben. Tabelle 4.102 zeigt die Energiedaten eines Doppelwäschers, der mit einem Durchlaufkühlsystem kombiniert ist.

| Energieverbrauch  | Spezifische Werte                                   |
|---|---|
| Strom (abhängig vom Gehalt an freien Fettsäuren im nicht raffinierten Öl) | 2 – 5 kWh/t nicht raffiniertes Öl                   |
| Dampf   | 39 – 50 kWh/t (50 – 100 kg/t nicht raffiniertes Öl) |

**Tabelle 4.102: Energiedaten eines Doppelwäschers, der mit einem Durchlaufkühlsystem kombiniert ist**

#### Anwendbarkeit

Geeignet für bestehende und neue Anlagen, gute Betriebszuverlässigkeit und leicht verfügbar. Die Qualität des Ausgangsmaterials für die Desodorierung sollte keine hohen Konzentrationen kurzkettiger (freier) Fettsäuren, z. B. Kokosöl, enthalten. Es wird Platz für den zweiten Wäscher benötigt.

#### Wirtschaftliche Aspekte

Investitionskosten für den zweiten Wäscher fallen an. Reduktion der Anlagenbetriebskosten.

#### Anlass für die Umsetzung

Sichert die Betriebsstabilität des Vakuumsystems für die Desodorierung. Einhaltung von gesetzlichen Bestimmungen bezüglich der Wasserverschmutzung und staatliche Energiesparpläne.

#### Referenzliteratur

[141, FEDIOL, 2002]

#### **4.7.4.12.2 Einzelner Wäscher in Kombination mit einem geschlossenen alkalischen Kreislauf bei der Desodorierung von pflanzlichen Ölen**

##### Beschreibung

Die Desodorierungsbrüden werden in einem Fettsäurewäscher behandelt. Der vorgereinigte Brüdenstrom wird mit dem Treibdampf eines Booster-Dampfstrahlers vermischt. Wenn das Ausgangsmaterial für die Desodorierung höhere Konzentrationen kurzkettiger Fettsäuren enthält, z. B. Kokosöl, reicht die Installation eines zweiten Wäschers zwischen dem Booster und dem barometrischen Hauptkondensator nicht aus, um die CSB-Belastung aus dem Durchlaufsystem auf ein akzeptables Maß zu reduzieren. In solchen Fällen kann die Gesamtbewertung der Technik zu dem Schluss führen, dass die Verschmutzungsfracht des rückgeführten Kühlwassers nicht akzeptabel ist, auch wenn der Energiebedarf des Durchlaufkühlsystems sehr gering ist. In solchen und ähnlichen Situationen können geschlossene Alkalisysteme verwendet werden. Durch die Installation eines geschlossenen Systems wird die Investition in einen zweiten Wäscher überflüssig.

In diesem Kühl-/Vakuumsystem wird das Kühlwasser in einem geschlossenen Kreislauf umgewälzt und die flüchtigen Bestandteile des Brüdenstroms aus der Desodorierung werden größtenteils im Hauptkondensator aufgefangen. Die Haupt- und Zwischenkondensatoren des Vakuumsystems können Teil dieses inneren Kühlwasserkreislaufs sein, mit einem Auslass zum Abwasserbehandlungssystem über die Seifenspaltungsanlage. Es müssen zwei Wärmetauscher installiert werden, um die wechselweise Reinigung zu ermöglichen. Es muss Natronlauge zugesetzt werden, die das Fett verseifen, um eine schnelle Belagbildung im Kreislauf durch fettige Stoffe zu verhindern. Der pH-Wert im barometrischen Kreislauf steigt auf etwa 9. Das Kondensat aus dem Strippdampf und dem Treibdampf der Booster liefern das Wasser, das für den alkalischen Kreislauf benötigt wird. Überschüssiges Wasser wird als Seifenlösung aus dem Kreislauf entnommen. Das Spalten der Seife erfolgt in einer gesonderten Abteilung. Die wässrige Phase der Seifenlösung aus dem Kreislauf wird Teil des Sauerwassers. Durch die Einführung eines geschlossenen Systems steigt der Dampfverbrauch für die Erzeugung desselben Dämpfungs-Vakuums.

Die Eingangstemperatur am Hauptkondensator liegt 5 °C höher als im offenen Kondensatorsystem, wodurch ein höherer Dampfverbrauch bei den Dampfstrahlgebläsen und damit ein höherer Kühlwasserbedarf entstehen. Dies kann diesen Prozess unter den für die Produktqualität erforderlichen physikalischen Bedingungen unmöglich machen. In diesem Fall kann der alkalische Kreislauf gekühlt werden, was zu höherem Stromverbrauch und geringerem Treibdampfverbrauch führt. In diesem Fall hat der Kreislauf eine tiefere Betriebstemperatur. Dieses System wird im Allgemeinen bei höheren Umgebungstemperaturen, z. B. im Sommer, eingesetzt.

Abbildung 4.63 zeigt ein einfaches Grundfließbild eines geschlossenen alkalischen Kreislaufs als Teil eines Vakuumsystems für die Desodorierung.

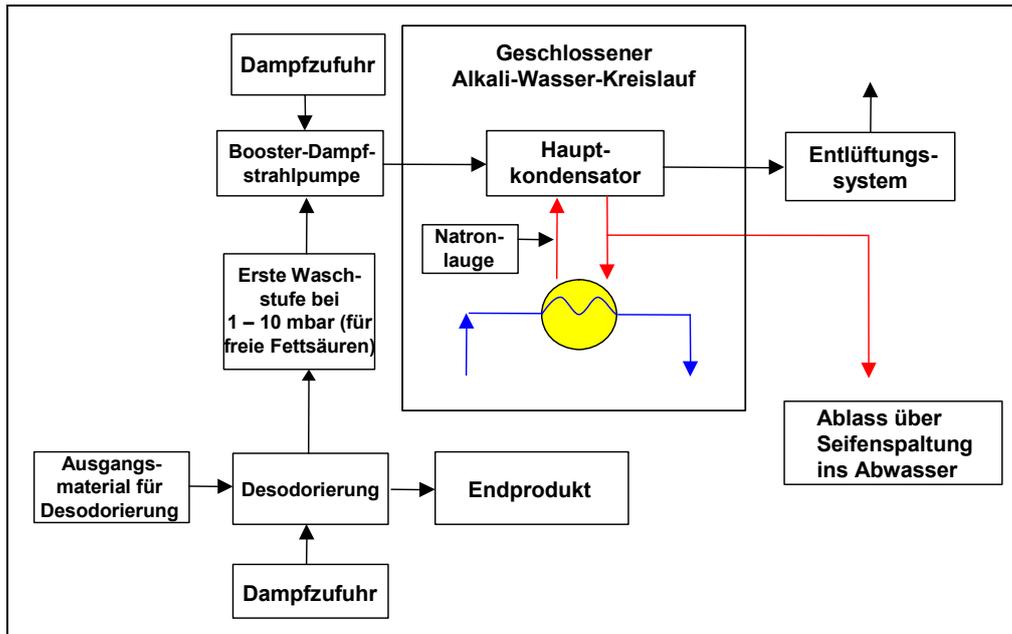


Abbildung 4.63: Grundfließbild eines geschlossenen alkalischen Kreislaufs mit Kühlung als Teil eines Vakuumsystems für die Desodorierung

Erreichbare Umweltvorteile

Mit dem geschlossenen alkalischen Kreislauf, ggf. mit zusätzlicher Kreislaufkühlung, wird die CSB-Fracht des Abwassers reduziert. Durch den geschlossenen Kreislauf sinkt der Frischwasserbedarf.

Medienübergreifende Auswirkungen

Erhöhte Zufuhr von Natronlauge für den Alkali-Kreislauf. Höherer Schwefelsäureverbrauch für die Seifenspaltung. Mehr Sauerwasser. Höhere Fracht aus der Seifenspaltung für die Kläranlage. Erhöhter Verbrauch von Strom und Dampf. Größere Sicherheits- und Umweltrisiken durch den Gebrauch von Kältemitteln wie Ammoniak zur Kühlung des alkalischen Kreislaufs.

Betriebsdaten

Im Vergleich zur Durchlaufkühlung (siehe Abschnitt 4.7.4.12.1) wird eine Verringerung des Abwasseranfalls von 99 % angegeben. Als Abwasseranfall werden 0,06 – 0,15 m³/t nicht raffiniertes Öl angegeben. Angaben zufolge steigt bei Verwendung eines geschlossenen Kreislaufs die Komplexität der Anlage, und ihre Zuverlässigkeit nimmt ab. Für den alkalischen Kreislauf werden interne Wärmetauscher, zusätzliche Pumpenkapazität und die Installation eines Kühlgeräts benötigt. Der Energiebedarf für die Desodorierung in einer Raffinerie macht mehr als 50 % des Gesamtenergiebedarfs aus. Die Installation des geschlossenen alkalischen Kreislaufs führt daher zu um 10 – 20 % höheren spezifischen Energieverbrauchswerten. Tabelle 4.103 zeigt die Energiedaten für ein geschlossenes Alkalisystem.

| Energieverbrauch  | Spezifische Werte                                    |  |
|---|--|--|
|   | Daten aus einer deutschen Beispielanlage             | Gemeldete Daten                                      |
| Strom (abhängig vom Gehalt an freien Fettsäuren im nicht raffinierten Öl) | 8 – 10 kWh/t nicht raffiniertes Öl                   | 8 – 20 kWh/t nicht raffiniertes Öl                   |
| Dampf   | 47 – 117 kWh/t nicht raffiniertes Öl (60 – 150 kg/t) | 39 – 117 kWh/t nicht raffiniertes Öl (50 – 150 kg/t) |

Tabelle 4.103: Energiedaten für einen geschlossenen alkalischen Kreislauf im Vakuumsystem der Desodorierung/Dämpfung

Anwendbarkeit

Anwendbar, wenn das Ausgangsmaterial für die Desodorierung keine hohen Konzentrationen kurzkettiger Fettsäuren, z. B. Kokosöl, enthält. Geeignet für neue und bereits bestehende Anlagen, leicht verfügbar. Anwendung kann durch Platzbedarf eingeschränkt sein.

In heißem Klima, wenn ein größeres Risiko einer Prozessinstabilität besteht, z. B. Fluktuationen im Vakuum, ist die Betriebszuverlässigkeit zusammen mit geeigneten Prozesssteuerungen akzeptabel. In gemäßigtem Klima und nach einer Behandlung zur Beseitigung von Brüdenfetten aus der Desodorierung ist die Technik bei sachgerechtem Betrieb sogar sehr zuverlässig, hauptsächlich wegen der robusten Dampfstrahlvakuumpumpen.

Wirtschaftliche Aspekte

Für Kreislaufsysteme fallen höhere Investitionskosten, Betriebskosten und ein größerer Energieverbrauch als bei Durchlaufsystemen an. Für gekühlte Kreislaufsysteme werden noch höhere Investitionskosten angegeben.

Referenzliteratur

[65, Germany, 2002, 141, FEDIOL, 2002, 189, Bockisch M, 1993]

#### 4.7.4.12.3 Einzelner Wäscher in Kombination mit Trockenkondensation bei der Desodorierung von pflanzlichen Ölen

Beschreibung

Trockenkondensationssysteme, die auch als Eiskondensationssysteme bezeichnet werden, werden zwischen dem Wäscher und dem Entlüftungssystem eingesetzt. Der Wäscher entfernt den größten Teil der freien Fettsäuren. Das Trockenkondensationssystem beseitigt die restlichen freien Fettsäuren und den Stripddampf, der zum Austreiben der freien Fettsäuren aus dem rohen Öl eingesetzt wurde. Der Dampf und die freien Fettsäuren werden auf den Wärmetauscherflächen des Trockenkondensationssystems bei Temperaturen von  $-30\text{ °C}$  ausgefroren/kondensiert. Die niedrige Temperatur wird durch die mechanische Kompression von Ammoniak und dessen anschließende Verdampfung in den Spiralen erzeugt. Die Kälteanlage verbraucht zusätzlich Strom und Kühlwasser. Nur die nicht-kondensierbaren Brüden passieren den Wäscher und das Trockenkondensationssystem und gelangen ins Vakuumsystem. Abbildung 4.64 zeigt ein Grundfließbild eines einzelnen Wäschers in Kombination mit einem Trockenkondensationssystem.

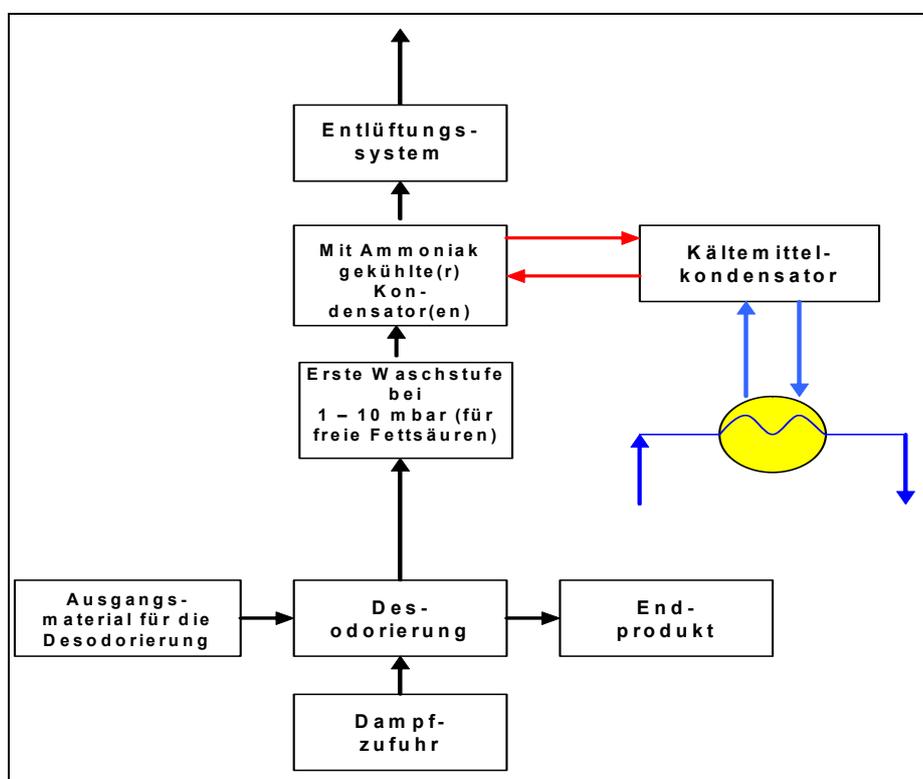


Abbildung 4.64: Grundfließbild eines Dämpfers in Kombination mit einem Wäscher und einem Trockenkondensationssystem

### Erreichbare Umweltvorteile

Rückgewinnung hochkonzentrierter Fettsäuren. Verringerung des Wasserverbrauchs. Geringere Abwassermenge und -verschmutzung. Geringerer Dampfverbrauch.

### Medienübergreifende Auswirkungen

Erhöhter elektrischer Strom für die Ammoniak-Kälteanlage. Durch den Gebrauch von Ammoniak für die Kühlung entstehen Gefahren für die Arbeits- und Umweltsicherheit, weil Ammoniak freigesetzt werden kann.

### Betriebsdaten

Angaben zufolge werden durch Trockenkondensation mehr als 95 % der kondensierbaren Brüden entfernt, sodass das nachgeschaltete Vakuumsystem (z. B. Wasserringpumpen) viel kleiner sein kann. Tabelle 4.104 zeigt Leistungsdaten aus einer Fallstudie eines Trockenkondensationssystems.

| Verbrauchsstufe  | Spezifische Werte  |
|--|--|
| Wasser für Wasserringpumpen und für das Kühlen der Kälteanlage zur Eiskondensation | 300 kg/t nicht raffiniertes Öl   |
| Strom (abhängig vom Gehalt an freien Fettsäuren im nicht raffinierten Öl)          | 10,5 - 21,5 kWh/t nicht raffiniertes Öl  |
| Dampf  | 5,5 - 15,5 kWh/t (20 - 150 kg/t) nicht raffiniertes Öl                               |
| Abwasser   | Bis zu 0,35 m <sup>3</sup> /t nicht raffiniertes Öl.<br>Keine Phosphate oder Sulfate |

**Tabelle 4.104: Leistungsdaten eines Beispiel-Trockenkondensationssystems**

### Anwendbarkeit

Anwendbar, wenn die destillative Entsäuerung (Neutralisation/Desodorierung (physikalische Raffination)) genutzt wird. Geeignet für neue und bereits bestehende Anlagen. Die Anwendbarkeit kann eingeschränkt sein durch Platzbedarf, geringe Fettgehalte im Brüden, Kapazität des destillativen Entsäuerers und äußere Sicherheitsanforderungen, z. B. durch den Einsatz von Ammoniak im Kühlsystem. Die Betriebszuverlässigkeit ist dank Steuertechnik gut. Das Vakuumsystem ist besser, da vom Wetter unabhängig.

### Wirtschaftliche Aspekte

Hohe Investitionskosten. Höhere Stromkosten. Hohe Wartungskosten. Höhere Kosten für elektrische Energie. Geringere Kosten durch weniger Dampf- und Kühlwasserverbrauch.

### Anlass für die Umsetzung

Erzeugung eines tieferen Vakuums zur Einhaltung strengerer Produktanforderungen. Wassereinsparung. Einhaltung gesetzlicher Bestimmungen bezüglich der Abwasserverschmutzung.

### Referenzliteratur

[65, Germany, 2002, 141, FEDIOL, 2002, 189, Bockisch M, 1993]

## **4.7.5 Molkereiprodukte**

### **4.7.5.1 Trennung der anfallenden Stoffe zur Optimierung der Verwendung, Wiederverwendung, Wiederverwertung und Entsorgung (und Minimierung des Wasserverbrauchs und der Abwasserkontamination)**

Diese Technik wird in Abschnitt 4.1.7.6 beschrieben.

#### Dokumentierte Beispiele für die Anwendung der Technik

Es gibt wahrscheinlich noch zahlreiche andere Möglichkeiten, wie diese Technik innerhalb des Sektors eingesetzt werden kann.

- Sammeln ausgelaufener oder verschütteter Zutaten und teilweise und vollständig verarbeiteter Produkte
- Sammeln von Molke, die nicht für die Herstellung von Mizithra-Käse, Säuglingsnahrung oder anderer Produkte vorgesehen ist
- Sammeln milchhaltigen Abwassers, das beim Anlaufen der Pasteurisatoren anfällt

- Verhindern, dass feste Abfälle aus der Zentrifuge ins Abwasser gelangen
- Sammeln und Rückgewinnung von Produkten/Produktmischungen bei Produktwechseln
- Trennung und Sammeln von Buttermilch, Vorspülflüssigkeit und Restfett bei der Herstellung von Butter, um diese Produkte dann in anderen Verfahren z. B. als Grundstoff für fettarme Brotaufstriche zu verwenden
- Sammeln der Spülflüssigkeit aus Joghurtbehältern
- Sammeln der Abtropfflüssigkeit von Joghurt und Obst innerhalb der Molkerei
- Sammeln und Entleerung falsch gefüllter Container zwecks Verwendung als Tierfutter, z. B. durch Mazeration der Verpackung

#### Anwendbarkeit

In allen Molkereien anwendbar.

#### Referenzliteratur

[13, Environment Agency of England and Wales, 2000, 39, Verband der Deutschen Milchwirtschaft (German Dairy Association), 2001, 42, Nordic Council of Ministers, et al., 2001, 74, Greek Ministry for the Environment, 2001, 134, AWARENET, 2002]

### **4.7.5.2 Trockenreinigung**

Diese Technik wird in Abschnitt 4.3.1 beschrieben.

#### Dokumentierte Beispiele für die Anwendung der Technik

Es gibt wahrscheinlich noch zahlreiche andere Möglichkeiten, wie diese Technik innerhalb des Sektors eingesetzt werden kann.

- Anwendung von Trockenreinigungsverfahren, um die Feststoffreste aus der Käseherstellung zu sammeln
- Zusammenkehren der Käsebruchverluste, anstatt sie in den Abfluss zu spülen
- Behandlung verschütteter Produkte wie Käsebruch, Joghurt oder Speiseeismischungen als Abfall, anstatt sie einfach in den Abfluss zu spülen
- Einsatz trockener Verfahren zur Sammlung von überschüssigem Salz, anstatt es einfach in den Abfluss zu spülen
- Ausrüstung der Abflüsse mit Sieben und/oder Auffangbehältern, um zu verhindern, dass Feststoffe in das Abwasser gelangen

#### Anwendbarkeit

In allen Molkereien anwendbar.

#### Referenzliteratur

[13, Environment Agency of England and Wales, 2000, 39, Verband der Deutschen Milchwirtschaft (German Dairy Association), 2001, 42, Nordic Council of Ministers, et al., 2001, 74, Greek Ministry for the Environment, 2001, 134, AWARENET, 2002]

### **4.7.5.3 Teilhomogenisierung der Marktmilch**

#### Beschreibung

Der Rahm wird zusammen mit einer kleinen Menge Magermilch homogenisiert. Der optimale Fettgehalt der Mischung beträgt 12%. Die restliche Magermilch fließt direkt aus dem Zentrifugalseparator in die Pasteuriseereinheit des Pasteurisators. Der homogenisierte Rahm wird dem Magermilchstrom vor Eintritt in den Aufheizbereich wieder zugemischt. Mithilfe dieser Technik kann die Größe des Homogenisators erheblich verringert werden, was zu Energieeinsparungen führt.

#### Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

#### Betriebsdaten

In einer Beispielmolkerei führte der Übergang zur Teilhomogenisierung in einer Pasteurisationslinie mit einer Nominalleistung von 25.000 l/h zu einer Verringerung der Homogenisierleistung auf 8.500 l/h. Der Stromverbrauch wurde durch die Installation eines kleineren Homogenisators mit 55 kW um rund 65% reduziert.

### Anwendbarkeit

In Molkereien anwendbar.

### Wirtschaftlichkeit

Kleinere Homogenisatoren bedeuten geringere Investitions- und Betriebskosten. Der kleinere Homogenisator kostet nur etwa 55% dessen, was ein Gerät kostet, mit dem die Nominalleistung der Linie behandelt werden könnte.

### Anlass für die Umsetzung

Geringere Investitions- und Energiekosten.

### Beispielanlagen

Wird in vielen modernen Molkereien eingesetzt.

### Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001]

#### **4.7.5.4 Steuerung von Milchtransport, Pasteurisation, Homogenisierung und CIP-Reinigung per Computer**

##### Beschreibung

Eine Beispielmolkerei (auch in Abschnitt 4.7.5.9 beschrieben) bekommt 450.000 Liter Milch in einer Qualität, die den Anforderungen der Richtlinie 92/46/EWG entspricht. Die Molkerei fordert von den Lieferanten den Einsatz mechanischer Melkanlagen, das Vorhandensein ausreichender Kühlkapazitäten und die Anwendung von HACCP. Das Grundfließbild der Verarbeitung in dieser Anlage ist in Abbildung 4.65 dargestellt.

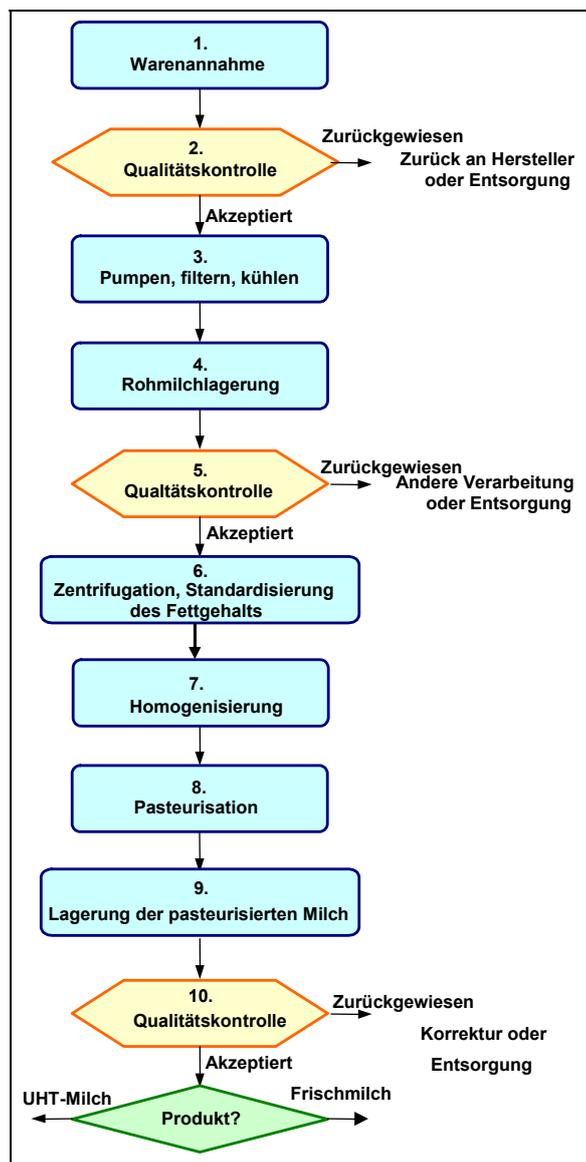


Abbildung 4.65: Grundfließbild für die Milchherstellung in einer Molkerei ]

Die Milch wird über zwei parallele geschlossene SPS-Systeme angenommen. Durch Einführung einer Technik mit Spezialventilen wurden die Milchverluste erheblich reduziert. Es wird berichtet, dass dort, wo diese Ventile eingesetzt wurden, keine Milchverluste beim Übergang zwischen den Rohren, beim Füllen von Tanks und durch menschliches Versagen mehr vorkommen und damit die Verunreinigung des Abwassers aus diesem Vorgang abgenommen hat.

Des Weiteren erfolgt die Pasteurisation der Milch in computergesteuerten Plattenwärmetauschern, die eine größere Oberfläche für den Wärmeaustausch haben als andere Geräte und mit automatischen Fettstandardisierungs- und Homogenisierungseinheiten ausgerüstet sind.

Die Verarbeitung findet in einem geschlossenen System statt. Die Steuerung der Lagerung und des Pumpens der Rohware, der Zwischen- und Endprodukte in die verschiedenen Verarbeitungseinheiten der Anlage wird mittels eines computergestützten Systems erledigt. Mit diesem System wurden die Verluste minimiert. Über dasselbe Steuerungssystem wird auch das CIP-System betrieben. Hier wird das letzte Spülwasser für den nächsten Reinigungsgang verwendet.

Die pasteurisierte Frischmilch wird in PE-Tüten oder PET-Flaschen abgefüllt.

#### Erreichbare Umweltvorteile

Weniger Milchverluste und geringere Kontamination des Abwassers. Durch Einsatz des computergesteuerten CIP-Systems ging auch der Verbrauch von Wasser und Reagenzien zurück.

### Betriebsdaten

Durch die größere Oberfläche, die für den Wärmeübergang zur Verfügung steht, und die Rezirkulation des Warmwassers ergeben sich bei der Pasteurisation gegenüber dem alten, vorher verwendeten Pasteurisiersystem Einsparungen von etwa 25% beim Energieverbrauch und etwa 50% beim Wasserverbrauch.

Durch die computergesteuerte Prozesssteuerung wird der Verlust von Milch bei der Anlieferung und der weiteren Verarbeitung vermieden oder verringert.

Es wird berichtet, dass die automatische Dosierung zu etwa 15%igen Einsparungen sowohl beim Wasserverbrauch als auch beim Verbrauch von Reinigungs- und Desinfektionsmitteln führt.

### Anwendbarkeit

In neuen und bereits bestehenden Anlagen anwendbar.

### Wirtschaftlichkeit

Die Investitionskosten sind hoch.

### Anlass für die Umsetzung

Geringere Kosten für Energie und Wasser.

### Beispielanlagen

Mindestens eine Molkerei in Ungarn.

### Referenzliteratur

[148, Sole, 2003]

## **4.7.5.5 Einsatz kontinuierlich arbeitender Pasteurisatoren**

### Beschreibung

Bei der kontinuierlichen Pasteurisation kommen Durchlaufwärmetauscher, z. B. Röhren- oder Plattenwärmetauscher, zum Einsatz. Diese haben Wärme-, Halte- und Kühlzonen. Um den Energieverbrauch und die Entstehung von Abwasser zu verringern, werden kontinuierlich arbeitende Pasteurisatoren anstelle von chargenweise arbeitenden Pasteurisatoren eingesetzt.

### Erreichbare Umweltvorteile

Weniger Energieverbrauch und geringere Abwassermengen im Vergleich zu chargenweise arbeitenden Pasteurisatoren.

### Betriebsdaten

Die Pasteurisation in Chargen erfolgt bei Temperaturen von 62-65 °C für bis zu 30 Minuten. Zu den kontinuierlichen Pasteurisationsverfahren gehören die Kurzzeiterhitzung (HTST, hohe Temperatur, kurze Zeit) und die Hoherhitzung (HHST, höhere Temperatur, kürzere Zeit). Die Kurzzeiterhitzung erfolgt bei 72-75 °C für 15-240 Sekunden. Bei der Hoherhitzung beträgt die Temperatur 85-90 °C für 1-25 Sekunden.

### Anwendbarkeit

In Molkereien anwendbar.

### Wirtschaftlichkeit

Geringere Kosten für Energie und Abwasserbehandlung.

### Referenzliteratur

[134, AWARENET, 2002]

## **4.7.5.6 Einsatz regenerativer Wärmetauschverfahren bei der Pasteurisation**

### Beschreibung

Pasteurisatoren sind im Allgemeinen mit regenerativen Gegenstromwärmezonen ausgerüstet. Die neu eingeleitete Milch wird von der heißen Milch, die die Pasteurisationszone verlässt, vorgewärmt.

Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

Betriebsdaten

Hierdurch können normalerweise Energieeinsparungen von über 90% erreicht werden.

Es wird berichtet, dass durch indirekten Wärmeaustausch zwischen dem bereits thermisch behandelten, abfließenden Produkt und dem einfließenden Produkt der spezifische Energieverbrauch in einer Beispielmolkerei von 148.000 kcal/t um 80% auf 29.000 kcal/t gesenkt werden kann. Es werden folgende Verfahrenstemperaturen angegeben:

- Ausgangstemperatur 4 °C
- durch Wärmetausch erzielte Erwärmungstemperatur 65 °C
- Pasteurisationstemperatur 78 °C
- durch Wärmetausch erzielte Abkühlungstemperatur 20 °C
- Temperatur der pasteurisierten Milch 4 °C.

Es wird auch berichtet, dass in der Molkerei Wärmetauscher zwischen dem einfließenden kalten Produkt, also der kalten Milch, und dem durch Vakuumexpansion gewonnenen Dampf nach der Ultrahocherhitzung (UHT) eingesetzt werden. Der spezifische Energieverbrauch von 251.000 kcal/t kann um 26% auf 185.000 kcal/t reduziert werden. Es werden folgende Verfahrenstemperaturen angegeben:

- Ausgangstemperatur der Milch 4 °C
- durch Wärmetausch erzielte Erwärmungstemperatur 70 °C
- Temperatur bei der UHT-Behandlung 140 °C
- Temperatur der UHT-Milch bei Abfüllung 25 °C.

Ein weiteres Beispiel wurde von einer neuen Molkerei berichtet, in der neun Plattenwärmetauscher mit höherer Wärmerückgewinnungsrate installiert wurden. Es wurden Berechnungen bezüglich der Steigerung der Effizienz von 85 auf 91% oder von 91 auf 95% durchgeführt. Die geschätzten Einsparungen belaufen sich für die zum Erhitzen benötigte Energie auf 2712 MWh/Jahr und beim Strom auf 542 MWh/Jahr; die Investitionskosten liegen bei 370.000 EUR, und die Amortisationsdauer beträgt 3,6 Jahre.

Anwendbarkeit

Wird in vielen Molkereien eingesetzt. In älteren Molkereien kann der Verbrauch an Energie zum Erhitzen und Abkühlen weiter reduziert werden, indem die alten Plattenwärmetauscher durch modernere, effektivere Modelle ersetzt werden.

Wirtschaftlichkeit

Senkung der Energiekosten.

Anlass für die Umsetzung

Senkung der Energiekosten.

Beispielanlagen

Eine Molkerei in Dänemark.

Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001, 75, Italian contribution, 2002]

#### **4.7.5.7 Verringerung der Reinigungsanforderungen bei Zentrifugen durch bessere Vorfiltration und Klärung der Milch**

Beschreibung

Durch Verbesserung der Vorfiltrations- und Klärverfahren für Milch können die Ablagerungen in den Zentrifugalseparatoren minimiert werden, sodass die Reinigungshäufigkeit abnimmt.

Erreichbare Umweltvorteile

Verringerung von Wasserverbrauch und Abwasserkontamination.

### Anwendbarkeit

In Molkereien anwendbar.

### Referenzliteratur

[134, AWARENET, 2002]

#### 4.7.5.8 Zweistufiges Trocknungsverfahren bei der Herstellung von Milchpulver

##### Beschreibung

Nachdem der Trockensubstanzgehalt der Milch in einem Verdampfer von 11% auf 50-60% erhöht wurde, kann die angedickte Milch weiter auf einen Trockensubstanzgehalt von 95-97% getrocknet werden. Für die Herstellung von Milchpulver werden Sprüh- oder Walzentrockner verwendet. Zwar werden durchaus Walzentrockner im Molkereisektor eingesetzt, und sie sind manchmal auch für spezielle Produkte nützlich, doch Sprühtrockner mit nachgeschaltetem oder integriertem Wirbelschichttrockner sind üblicher (siehe Figure 2.13). Die Gründe sind ein geringerer Energieverbrauch, ein im Wesentlichen staubfreies Produkt und eine geringere Wärmebelastung des Produktes.

Eine Sprühtrocknung, die mit einem nachgeschalteten Wirbelschichttrockner arbeitet, wird auch als zweistufige Trocknung bezeichnet. Abbildung 4.66 zeigt ein zweistufiges Trocknungsverfahren mit einem Sprühtrockner mit Zentrifugalzerstäuber und einem separaten, externen Wirbelschichttrockner. Die Abluft wird über einen CIP-Filter geleitet, der aus einem Filterschlauch ohne Zyklon besteht (siehe Abschnitt 4.4.3.7.1).

Bei der zweistufigen Trocknung kann neben einer wirksameren Energieausnutzung auch eine geringere Restfeuchte und damit eine geringere Beeinträchtigung der Produktqualität erreicht werden. Die Feststoffe verlassen den Sprühtrockner mit einer Restfeuchte von 3-5%. Der letzte Trocknungsschritt findet unter schonenden Bedingungen und mit geringem Energieaufwand statt.

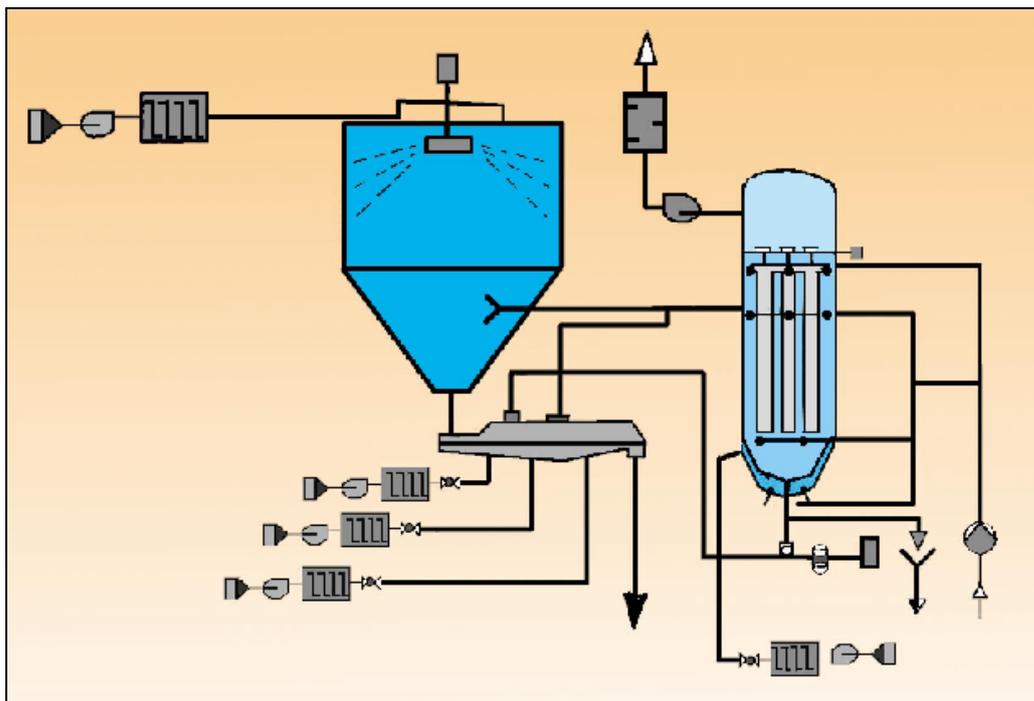


Abbildung 4.66: Zweistufiges Trocknungsverfahren] in einer großen Molkerei

##### Erreichbare Umweltvorteile

Geringerer Energie- und Wasserverbrauch. Geringere Staubemissionen.

##### Medienübergreifende Effekte

Sprühtrockner erzeugen Lärm, und es können explosive Staub-Luftmischungen entstehen.

Betriebsdaten

Eine große Molkerei in Deutschland stellt Magermilch- und Süßmolkenpulver her. Es werden 240.000 t Rohmilch verarbeitet. Die Produktionsmenge an Milch- und Molkenpulver beträgt 19.000 t. In der Molkerei wird ein zweistufiges Trocknungssystem mit einer Leistung von 1 t/h eingesetzt. Das Abgasvolumen beträgt 45.000 m<sup>3</sup>/h. Auf das Trocknungsverfahren entfällt mit 58% bzw. 39 Mio. kWh der größte Teil des Gesamtverbrauchs der Anlage an thermischer Energie, der sich im Jahr 2000 auf 67,5 Mio. kWh belief. 30% des gesamten Stromverbrauchs, d. h. 18 Mio. kWh, wurden dem Bericht zufolge dem Trocknungsverfahren zugerechnet.

In dieser Beispielmolkerei betrug der berichtete spezifische Energieverbrauch 315,8 kWh/t Produkt bzw. 25 kWh/t Rohmilch. Der spezifische Verbrauch an thermischer Energie belief sich auf 2.052,6 kWh pro t Produkt bzw. 162,5 kWh/t Rohmilch. Berücksichtigt man, dass eine Energiemenge von etwa 600 kWh nötig ist, um eine Tonne Wasser zu verdampfen, dann liegen diese Werte nahe am theoretischen Energiebedarf. Der gesamte Wasserverbrauch für die Trocknung war mit 9.500 m<sup>3</sup> oder 0,5 m<sup>3</sup>/t Produkt bzw. 0,04 m<sup>3</sup>/t Rohmilch ebenfalls gering.

Es wird berichtet, dass bei Einsatz einer integrierten Wirbelschichttrocknung der für die Trocknung benötigte Energieverbrauch um etwa 20% verringert werden kann. Die Investition beinhaltet zusätzliche Kapital- und Betriebskosten.

Feuer- und Explosionsschutzmaßnahmen sind erforderlich. Ein Beispiel für einen Frühwarnfeuersalarm ist der Kohlenmonoxidnachweis.

Anwendbarkeit

In Molkereien anwendbar.

Wirtschaftlichkeit

Hohe Kapitalkosten.

Anlass für die Umsetzung

Geringerer Energie- und Wasserverbrauch.

Beispielanlagen

Eine große Molkerei in Deutschland, die Milchpulver herstellt.

Referenzliteratur

[39, Verband der Deutschen Milchwirtschaft (German Dairy Association), 2001]

#### **4.7.5.9 Einsatz eines aseptischen Verpackungssystems ohne die Notwendigkeit einer Aseptikkammer**

Beschreibung

Eine Beispielmolkerei (auch in Abschnitt 4.7.5.4 beschrieben) bekommt 450.000 Liter Milch in einer Qualität, die den Anforderungen der Richtlinie 92/46/EWG entspricht. Die Molkerei fordert von den Lieferanten den Einsatz mechanischer Melkanlagen, das Vorhandensein ausreichender Kühlkapazitäten und die Anwendung von HACCP.

Die Milch wird einem UHT-Verfahren unterworfen, danach homogenisiert und aseptisch „on-line“ verpackt. Bei diesem Verfahren werden hocheffiziente Röhrenwärmetauscher eingesetzt. Die ziegelförmigen Verpackungen bestehen aus einem laminierten Material auf Papiergrundlage, das mehrere Schichten Kunststoffolie und Aluminiumfolie enthält. Die Verpackungen werden aus einem kontinuierlichen Materialband geformt, das der Abfüllanlage über ein Sterilisationsbad aus Wasserstoffperoxid zugeführt wird. Danach wird das Band um die sterile Produktzufuhrleitung zu einem Schlauch geformt; die entsprechenden Längs- und Quernähte entstehen durch Hitzeversiegelung der inneren Kunststoffschichten während des Abfüllvorgangs. Das kontinuierliche aseptische Verpackungssystem erfordert keine Aseptikkammer mehr.

In Abbildung 4.67 ist das Verpackungsverfahren schematisch dargestellt. Die Nummerierung der Arbeitsschritte in Abbildung 4.67 schließt an Abbildung 4.65 an.

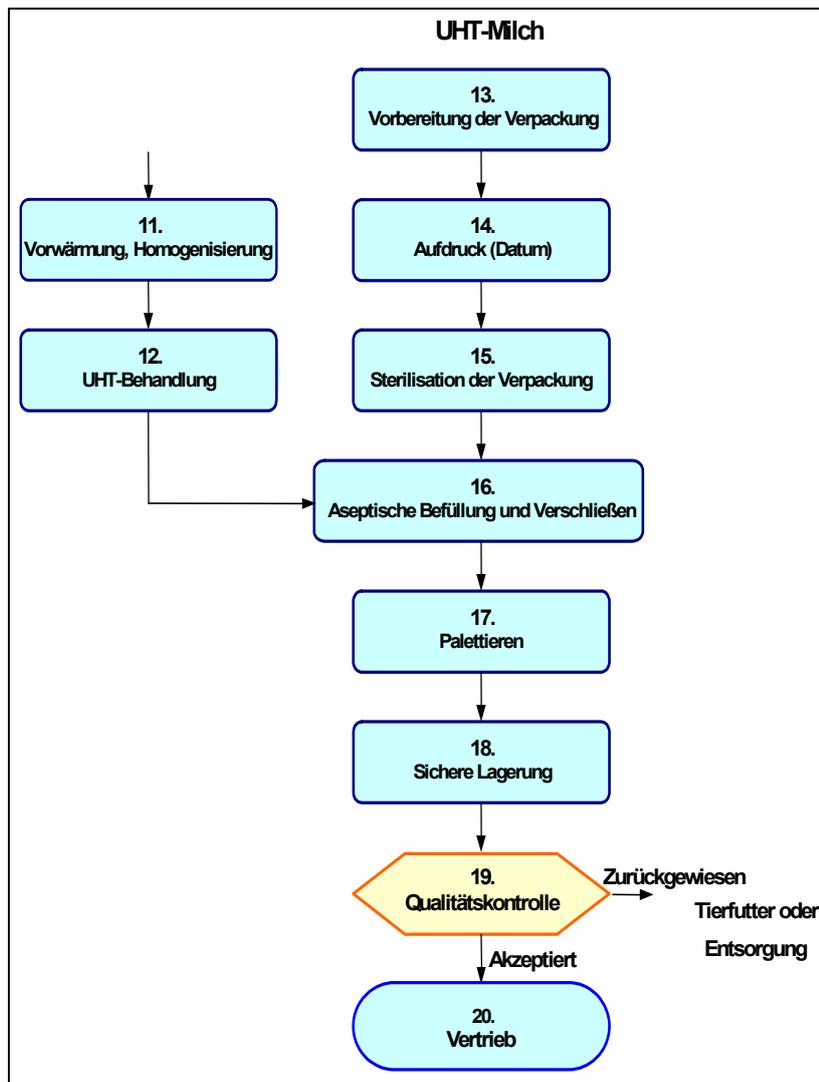


Abbildung 4.67: Aseptische Abfüllung von UHT-Milch ohne Aseptikkammer

Erreichbare Umweltvorteile

Energieeinsparungen bei der Hitzebehandlung, weniger Verpackungsabfall und weniger Milchverlust.

Betriebsdaten

Die Verderbquote bei Einsatz dieses Systems wird mit unter 0,5% angegeben.

Anwendbarkeit

In neuen und bereits bestehenden Anlagen anwendbar.

Wirtschaftlichkeit

Die Investitionskosten sind hoch.

Anlass für die Umsetzung

Geringere Kosten für Energie und Wasser.

Beispielanlagen

Mindestens eine Molkerei in Ungarn.

Referenzliteratur

[148, Sole, 2003]

#### 4.7.5.10 Automatische Erkennung des Übergangs zwischen Produkt- und Wasserphasen

##### Beschreibung

Bevor die Anlage in Betrieb genommen wird, sind die Rohre normalerweise mit Wasser gefüllt. Das Produkt drückt dann das Wasser durch ein Ablaufventil heraus. Früher erfolgte das Schließen der Ablaufventile von Hand nach Sichtkontrolle oder automatisch nach Ablauf der für die Befüllung des Rohrsystems mit dem Produkt erforderlichen Zeit. Um die Übergänge zwischen Wasserphase und Produktphase verlässlich zu erkennen, erfolgt jetzt in vollautomatischen Produktionslinien eine kontinuierliche Überwachung, z. B. durch Messung des Volumens mit Hilfe von Durchfluss- (siehe Abschnitt 4.1.8.4) bzw. Dichtetransmittern, durch Dichtebestimmung mit Hilfe von Leitfähigkeitstransmittern (siehe Abschnitt 4.1.8.5.2) und durch den Einsatz von Streulichtsensoren (siehe Abschnitt 4.1.8.5.3), zur Unterscheidung zwischen Wasser und Produkt.

Diese Verfahren können eingesetzt werden, um Produkt aus der Vorspülung der CIP-Reinigung, bei Beginn, Ende und Produktwechsel im HTST-Verfahren und beim Spülen anderer Geräte oder Leitungen rückzugewinnen.

##### Erreichbare Umweltvorteile

Geringere Verschmutzung des Abwassers.

##### Betriebsdaten

Berichten zufolge sind Streulichtsensoren am zuverlässigsten und genauesten und haben kürzere Reaktionszeiten als andere Methoden der automatischen Überwachung. Es wird berichtet, dass bei Einsatz von Streulichtsensoren die Menge an milchhaltigem Spülwasser, das an die Kläranlage weitergegeben wird, auf einige wenige Liter pro Betriebsstart reduziert werden kann. Außerdem können die Produktverluste um 50% gesenkt werden. Bei Abfülllinien für flüssige Milchprodukte konnte mit Hilfe solcher Sensoren die Menge der beim Produktwechsel entstehenden Mischungen um 30-40% verringert werden.

In einer Beispielanlage, die mit Leitfähigkeitstransmittern arbeitete, konnte der BSB-Wert im Abwasser um 30% gesenkt werden. Es ist notwendig, die Dichtetransmitter regelmäßig zu kalibrieren.

##### Anwendbarkeit

Transmitter und Sensoren können sowohl in neue als auch bereits bestehende Anlagen eingebaut werden. Bei der Installation sind geringe Veränderungen des Prozesskontrollsystems notwendig.

Leitfähigkeitstransmitter werden meistens in CIP-Zentren zur Erkennung des Übergangs zwischen Wasser und Reinigungslösung eingesetzt, aber sie können auch für Produktionslinien verwendet werden. Automatische Streulichtsensoren sind im Handel erhältlich. Sie können auch für die Standardisierung des Fettgehalts der Milch verwendet werden.

##### Wirtschaftlichkeit

Der Preis eines Streulichtensors beträgt etwa 2.700 EUR (2001). Die Kosten für die Implementierung der Prozesskontrolle beinhaltet nicht nur den Preis für die Sensoren, sondern auch die dazugehörige Hard- und Software, d. h. Transmitter und Anzeigeeinstrumente.

##### Anlass für die Umsetzung

Weniger Produktverluste und geringere Kosten für die Abwasserbehandlung.

##### Beispielanlagen

Eine Beispielmolkerei in Finnland verfügt über 61 automatische Streulichtsensoren in ihren Verarbeitungslinien. Leitfähigkeits- und Durchflusstransmitter sind in den nordischen Ländern weit verbreitet.

##### Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001]

#### 4.7.5.11 Einbau von Lagertanks in der Produktionslinie zur Minimierung der Produktumwälzung in den Pasteurisatoren

##### Beschreibung

Eine Produktionslinie kann so ausgelegt werden, dass die Leistungsfähigkeit der Einzelkomponenten mit der der anderen Komponenten optimal abgestimmt wird, damit Produktstaus oder Produktionsunterbrechungen auf-

grund fehlenden Produktes an bestimmten Stellen der Linie verhindert werden. Spätere Veränderungen in der Produktionslinie oder dem Abfüllplan könnten jedoch das Gleichgewicht stören und zu Unterbrechungen des kontinuierlichen Betriebs führen.

Falls beispielsweise die Kapazität der Lagertanks in der Linie zu klein ist im Vergleich zum Ausstoß der Pasteurisatoren der Pasteurisationslinie, muss die Milch im Pasteurisator mehrere Male am Tag umgewälzt werden. Das verbraucht Energie, beeinträchtigt die Produktqualität und ist in der Richtlinie des Rates 92/46/EWG [191, EC, 1992] geregelt. Außerdem erhöhen längere Unterbrechungen die Reinigungshäufigkeit für die Pasteurisatoren.

Unterbrechungen in der Linie und das Umwälzen der Milch im Pasteurisator können vermieden oder minimiert werden, wenn Größe/Anzahl der Lagertanks in der Linie an den Ausstoß des Pasteurisators angepasst und die Produktwechsel optimiert werden.

### Erreichbare Umweltvorteile

Energie wird hauptsächlich dadurch eingespart, dass weniger Wasser zum Kühlen verbraucht wird. Der Gesamtverbrauch an elektrischer Energie, die für den Betrieb der Pumpen, Homogenisatoren und Zentrifugal-separatoren nötig ist, verringert sich ebenfalls, und die gesamte Verarbeitungsdauer wird kürzer. Mit sinkender Reinigungshäufigkeit verringert sich der Verbrauch an Energie, Wasser und Chemikalien. Die negativen Auswirkungen der längeren Wärmebehandlung auf die Produktqualität werden ebenfalls reduziert.

### Betriebsdaten

In einer Beispielmolkerei führte der Einbau von Lagertanks in der Pasteurisationslinie vor der Abfüllanlage zusammen mit einer Automatisierung der Produktwechsel zu einer Abnahme der Verarbeitungsdauer um 30%. Die jährlichen Energieeinsparungen in dieser Molkerei beliefen sich auf 250 MWh an elektrischer und 230 MWh an thermischer Energie. Die geschätzte Amortisationszeit beträgt 4,5 Jahre.

### Anwendbarkeit

In Molkereien anwendbar. Platzmangel könnte bei bestehenden Anlagen eine Einschränkung darstellen.

### Wirtschaftlichkeit

Geringere Betriebskosten, z. B. weniger Energie- und Wasserverbrauch.

### Anlass für die Umsetzung

Diese Lösung bietet mehr Flexibilität, bessere Qualität und geringere Betriebskosten.

### Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001]

## **4.7.5.12 „Komponentenabfüllung“ mit bedarfssynchroner Mischung**

### Beschreibung

Mit einem Abfüllanlagenkonzept, das „Komponentenabfüllung“ genannt wird, können Milchprodukte so spät wie möglich, vorzugsweise direkt vor der Abfüllung, diversifiziert werden. In der entsprechenden Maschine gibt es zwei Leitungen, eine für Magermilch und die andere für Milch mit einem standardisierten Fettgehalt. Beide Produkte werden bei der Abfüllung in dem für das entsprechende Produkt erforderlichen Verhältnis gemischt. Beispielsweise könnte eine Molkerei drei verschiedene Arten von Milch mit drei verschiedenen Fettgehalten herstellen, und zwar durch Veränderung der Mengen, die durch die zwei Leitungen zugeführt werden. Mit dieser Technik können Verluste von Produkt und Verpackungsmaterial, die bei Produktwechseln auftreten, vermieden werden. Mit der Abfüllung von Komponenten nehmen auch die Notwendigkeit von Lagertanks in der Linie und die entsprechenden Reinigungsanforderungen ab.

### Erreichbare Umweltvorteile

Geringere Produkt- und Verpackungsverluste. Weniger Wasserverbrauch, z. B. für die Reinigung, und geringere Abwasserkontamination.

### Betriebsdaten

Normalerweise können im herkömmlichen Abfüllbetrieb leicht 75-100 Liter Milch beim Produktwechsel verlorengehen.

Anwendbarkeit

In neuen und bereits bestehenden Anlagen aus dem Bereich der Milchverarbeitung anwendbar. Veränderungen an den Leitungen und ein automatisches System sind erforderlich, bevor die Maschine an eine bereits bestehende Anlage angeschlossen werden kann.

Wirtschaftlichkeit

Der Preis einer neuen Abfüllmaschine für Komponenten mit einer Abfülleistung von 12.000-12.500 Packungen/h beträgt etwa 1 Mio. EUR (2001) ohne eventuell erforderliche Prozessmodifikationen. In vielen Fällen kann eine Komponentenabfüllmaschine mehrere herkömmliche Füller ersetzen.

Anlässe für die Umsetzung

Die Flexibilität der Produktion wird erhöht, wodurch ein mehr verbraucherorientierter Ansatz ermöglicht wird. Je schneller das Produkt in die Handelsketten kommt, desto weniger Kühllagerplatz wird benötigt.

Beispielanlagen

Es gibt insgesamt drei Komponentenabfüllanlagen in den nordischen Ländern, darunter eine in Finnland.

Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001, 199, Finland, 2003]

**4.7.5.13 Butter****4.7.5.13.1 Minimierung der Verluste in der Butterherstellung**Beschreibung

Angesichts der hohen Viskosität des Rahms kann der Rahmerhitzer vor der Reinigung mit Magermilch gespült werden, die dann aufgefangen und verwertet wird. Dadurch verringern sich die Fettverluste. Buttermilch, die als Nebenprodukt entsteht, kann als Produkt verwendet werden und muss nicht z. B. ins Abwasser geleitet werden. Diese Produkte können dann z. B. als Grundlage für fettarme Brotaufstriche verwendet werden.

Erreichbare Umweltvorteile

Weniger Abfall.

Anwendbarkeit

In der Herstellung von Butter und Sahne anwendbar.

Anlass für die Umsetzung

Weniger Abfall und höhere Produktausbeute.

**4.7.5.14 Käse****4.7.5.14.1 Standardisierung des Proteins in der Käsereimilch durch Ultrafiltration (UF)**Beschreibung

Durch Ultrafiltration (UF) kann das in der Käsereimilch enthaltene Protein standardisiert werden. Die Milch fließt unter Druck über eine Membran, die die Proteinmoleküle zurückhält und damit den Proteingehalt im Retentat erhöht. Die Porengröße der Membran beträgt etwa 10 bis 100 nm.

Da sich die Käseausbeute pro Einheit verarbeiteter Milch durch UF erhöht, entsteht weniger Molke als bei einer herkömmlichen Standardisierung. Zwar erfordert die UF mehr Strom, thermische Energie und Wasser als eine herkömmliche Standardisierung, aber in der industriellen Produktion wird der höhere Verbrauch an Wasser und Energie durch die höhere Ausbeute an Käse kompensiert.

Das Permeat aus der Ultrafiltrationsanlage wird dann im Umkehrosmoseverfahren weiterbehandelt. Das Wasser aus der Umkehrosmose hat Trinkwasserqualität und kann zu Reinigungszwecken eingesetzt werden.

Erreichbare Umweltvorteile

Weniger Energie- und Wasserverbrauch, weniger Molke und weniger Abwasser als bei der herkömmlichen Standardisierung.

### Medienübergreifende Effekte

Die Membranen müssen gereinigt werden. Da dies mit Chemikalien geschieht, muss der Filtrationsring mit großen Wassermengen gut gespült werden. Entsorgung der gebrauchten Membranen.

### Betriebsdaten

Eine UF-Einheit in einer dänischen Molkerei besteht aus 10 Spiralwickelmodulen mit Polymermembranen, vier Pumpen und den entsprechenden Durchflusstransmittern und Regelventilen. Die Filtrationsleistung beträgt 65.000 l/h. Der Proteingehalt der Milch wird durch Kontrolle des Verhältnisses zwischen Zustrom und Permeat auf 3,7-3,8% standardisiert. Im Vergleich zum herkömmlichen Standardisierungsverfahren ist die Käseausbeute höher, d. h. es wurde eine etwa 12%ige Verringerung des Milchvolumens erzielt. Für eine Produktion von 25.000 t Schnittkäse pro Jahr wurden die in Tabelle 4.105 angegebenen geschätzten Einsparungen im Wasser- und Energieverbrauch berechnet.

|                            |                            |               |
|----------------------------|----------------------------|---------------|
| <b>Elektrische Energie</b> | 473 MWh/Jahr               | 19 kWh/t Käse |
| <b>Thermische Energie</b>  | 1235 MWh/Jahr              | 49 kWh/t Käse |
| <b>Wasser</b>              | 7.500 m <sup>3</sup> /Jahr | 300 l/t Käse  |

**Tabelle 4.105: Einsparungen beim Wasser- und Energieverbrauch in einer Molkerei, die den Proteingehalt durch Ultrafiltration standardisiert**

UF-Membranen haben eine begrenzte Lebensdauer von 1-3 Jahren, je nach Einsatzbereich. Nach dem Einsatz werden sie verbrannt oder auf die Mülldeponie verbracht.

### Anwendbarkeit

UF kann sowohl für Magermilch als auch für Molke eingesetzt werden. UF-Anlagen können dank ihres geringen Platzbedarfs in neuen und bereits bestehenden Anlagen installiert werden.

### Wirtschaftlichkeit

Die Investitionskosten sind hoch. Die Amortisationszeit ist nur bei ausreichend hoher Kapazität akzeptabel. In der dänischen Molkerei beispielsweise werden die Investitionskosten auf 430.000 EUR und die Amortisationsdauer auf 5,9 Jahre geschätzt.

### Anlass für die Umsetzung

Mit dieser Technik kann Käse in homogener Qualität hergestellt werden. Sie bietet außerdem eine höhere Flexibilität bei der Herstellung verschiedener Käsesorten.

### Beispielanlagen

Eine Molkerei in Dänemark.

### Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001]

#### **4.7.5.14.2 Verringerung der Fett- und Käsefeinanteile in der Molke**

### Beschreibung

Um den Anteil an Fett- und Käsefeinstoffen in Molke zu verringern, werden zunächst während der Verarbeitung dem Käsebruch soviel Fett und Proteine entzogen wie möglich; danach wird die Molke gesiebt, um die restlichen Feinanteile zu sammeln.

### Erreichbare Umweltvorteile

Geringerer Produktverlust. Falls Molke in die Kläranlage geleitet werden darf, ist die Belastung mit Verunreinigungen geringer, siehe auch Abschnitt 4.7.5.14.3 zur Minimierung dieser Belastung.

### Anwendbarkeit

In allen Anlagen zur Käseherstellung anwendbar.

### Wirtschaftlichkeit

Optimierung der Produktionskosten. Geringere Kosten für die Abwasserbehandlung.

Anlass für die Umsetzung  
Geringerer Produktverlust.

Referenzliteratur  
[134, AWARENET, 2002]

#### 4.7.5.14.3 Minimierung der Produktion von Sauermolke und ihrer Abgabe in die Kläranlage

##### Beschreibung

Bei der Käseherstellung bleiben etwa 90% der eingesetzten Milch als Molke übrig. Bei Sauermilchkäse werden Milchsäurebakterien als Mutterkulturen auf einem Medium gezüchtet, und dann werden die Starterkulturen vermehrt und der Milch zugesetzt, um Käse herzustellen. Die Sauermolke wird nach der Bildung des Käsebruchs abgetrennt. Wenn Sauermolke in eine Kläranlage geleitet wird, kann sie dort niedrige pH-Werte verursachen. Damit das nicht geschieht, werden Verschüttungen durch Abtropfenlassen der Oberteile oder Plattformen der Salzbottiche vermieden. Außerdem kann Molke so schnell verarbeitet werden, dass weniger Sauermolke durch Bildung von Milchsäure entsteht.

Erreichbare Umweltvorteile  
Geringere Verschmutzung des Abwassers.

Anwendbarkeit  
In der Herstellung von Sauermilchkäse, z. B. Hüttenkäse, Quark und Mozzarella, anwendbar.

Wirtschaftlichkeit  
Geringere Kosten für die Abwasserbehandlung.

Referenzliteratur  
[13, Environment Agency of England and Wales, 2000]

#### 4.7.5.14.4 Rückgewinnung und Verwendung von Molke

##### Beschreibung

Bei der Käseherstellung bleiben etwa 90% der eingesetzten Milch als Molke übrig. Süßmolke entsteht bei der Herstellung von Schnittkäse wie z. B. Cheddar oder Schweizer Käse durch den Zusatz von Lab. Sauermolke entsteht, nachdem dem Käsebruch Salz zugesetzt wurde, um überschüssige Flüssigkeit zu entfernen. Süßmolke wird aufgefangen und im Prozess oder in anderen Prozessen zur Herstellung von Nebenprodukten wiederverwendet, z. B. für die Rückgewinnung von Protein, als Tierfutter, zur Herstellung von Mizithra, als Nahrungsergänzungsmittel oder für Babynahrung. Selbst wenn die Sauermolke ohne das vorherige Entfernen des Salzes nicht innerhalb des Prozesses wiederverwendet werden kann, (siehe Abschnitt 4.7.5.14.6), kann diese Molke trotzdem entweder aufgefangen oder durch Verdampfen aufkonzentriert und als Tierfutter verwendet werden.

Erreichbare Umweltvorteile  
Geringere Verschmutzung des Abwassers. Weniger Abfälle, d. h. die Molke wird wiederverwendet.

Betriebsdaten  
In Tabelle 4.106 sind die Parameter eines typischen Abwassers aus der Käseherstellung mit und ohne Rückgewinnung der Molke angegeben.

| Parameter           | Anlage mit Molkenrückgewinnung | Anlage ohne Molkenrückgewinnung |
|---------------------|--------------------------------|---------------------------------|
|                     | mg/l                           |                                 |
| BSB <sub>5</sub>    | 2.397                          | 5.312                           |
| CSB                 | 5.312                          | 20.559                          |
| Fett                | 96                             | 463                             |
| N <sub>gesamt</sub> | 90                             | 159                             |
| P <sub>gesamt</sub> | 26                             | 21                              |

Tabelle 4.106: Zusammensetzung des Abwassers aus der Käseherstellung

### Anwendbarkeit

In allen Anlagen zur Käseherstellung anwendbar.

### Wirtschaftlichkeit

Geringere Kosten für die Abwasserbehandlung.

### Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001, 134, AWARENET, 2002]

#### **4.7.5.14.5 Rückgewinnung der Sauermolke durch Verdampfung**

### Beschreibung

Bei der Käseherstellung bleiben etwa 90% der eingesetzten Milch als Molke übrig. Sauermolke entsteht, nachdem dem Käsebruch Salz zugesetzt wurde, um überschüssige Flüssigkeit zu entfernen. Sauermolke kann innerhalb des Verfahrens wiederverwendet oder als Tierfutter verwendet werden, und zwar entweder direkt oder nach der Trocknung durch Verdampfen. Das kondensierte Wasser kann zur Reinigung genutzt werden.

### Erreichbare Umweltvorteile

Weniger Abfälle, d. h. die Molke wird verwendet. Geringere Verschmutzung des Abwassers.

### Medienübergreifende Effekte

Energieverbrauch.

### Anwendbarkeit

In allen Anlagen zur Käseherstellung anwendbar.

### Referenzliteratur

[134, AWARENET, 2002]

#### **4.7.5.14.6 Rückgewinnung von Molke durch Salzzug mittels Umkehrosmose**

### Beschreibung

Bei der Käseherstellung bleiben etwa 90% der eingesetzten Milch als Molke übrig. Sauermolke entsteht, nachdem dem Käsebruch Salz zugesetzt wurde, um überschüssige Flüssigkeit zu entfernen. Sauermolke kann im Prozess ebenso wie Süßmolke (siehe Abschnitt 4.7.5.14.4) wiederverwendet werden, aber nur dann, wenn zuvor das Salz durch Umkehrosmose entzogen wurde.

### Erreichbare Umweltvorteile

Weniger Abfälle, d. h. die Molke wird wiederverwendet. Geringere Verschmutzung des Abwassers.

### Medienübergreifende Effekte

Das Permeat aus der Umkehrosmose ist stark salzhaltig.

### Anwendbarkeit

In allen Anlagen zur Käseherstellung anwendbar.

### Wirtschaftlichkeit

Hohe Kosten.

### Referenzliteratur

[13, Environment Agency of England and Wales, 2000]

#### **4.7.5.14.7 Nutzung der in der warmen Molke enthaltenen Wärmeenergie für die Vorwärmung von Käsereimilch**

##### Beschreibung

Die zu verarbeitende Milch wird mit Hilfe der Wärme, die der entstandenen Molke entzogen wird, erwärmt. Für die Zirkulation des Wassers sind Wärmetauscher und Tanks erforderlich. Damit werden Energieeinsparungen für die Erwärmung der einströmenden Milch und für die Kühlung der verarbeiteten Molke erzielt.

##### Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

##### Betriebsdaten

In einer dänischen Beispielmolkerei wird die Käsereimilch mit der Wärme aus einem geschlossenen System, in dem Wasser mit einer Temperatur von 34,5 °C zirkuliert, von 12 °C auf 32 °C erwärmt. Dabei sinkt die Temperatur des Wassers auf 13 °C; es wird dann in der Kühlzone des Molkepasteurisators, in der die Molke von 36 °C auf 14,5 °C abgekühlt wird, wieder erhitzt. Für den Wasserkreislauf wurden neben den Plattenwärmetauschern zwei Puffertanks mit einem Fassungsvermögen von je 150 m<sup>3</sup> installiert. Bei angenommenen 250 Mio. kg Molke pro Jahr werden schätzungsweise 1.200 MWh Strom, 6.065 MWh thermische Energie und 4.200 m<sup>3</sup> Wasser pro Jahr eingespart.

##### Anwendbarkeit

In neuen und bereits bestehenden Anlagen anwendbar. In bereits bestehenden Anlagen kann Platzmangel eine Einschränkung darstellen.

##### Wirtschaftlichkeit

In der dänischen Beispielmolkerei wurde eine Kostenschätzung durchgeführt, doch diese bezog sich auf die gesamte Molkeverarbeitung einschließlich einer Umkehrosmoseanlage sowie der Wärmebehandlung und Wärmerückgewinnung. Die Gesamtkosten beliefen sich auf 1,6 Mio. EUR mit einer Amortisationszeit von 3,8 Jahren.

##### Anlass für die Umsetzung

Geringere Energiekosten.

##### Beispielanlagen

Eine Molkerei in Dänemark.

##### Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001]

#### **4.7.5.14.8 Käsereifung bei hohen Temperaturen mit späterer Befeuchtung und Ionisierung der zirkulierenden Luft**

##### Beschreibung

Bei der Herstellung von Käse wird die Lufttemperatur erhöht, um die Reifezeiten zu verkürzen. Damit verringern sich die erforderlichen Lagerkapazitäten, und es wird weniger Energie für Kühlung und Belüftung benötigt. Da mit höheren Temperaturen das Risiko der Austrocknung des Käses und der Kontamination mit Schimmelpilzen einhergeht, wird die zirkulierende Luft angefeuchtet und in einer Entladungsröhre gereinigt, in der die Luft, die durch die Ventilationskanäle passiert, ionisiert wird. Da die Ionen in der zirkulierenden Luft mit den darin enthaltenen Staubteilchen, Mikroorganismen und Viren reagieren, wird sie wirksam von diesen Kontaminationsverursachern befreit.

##### Erreichbare Umweltvorteile

Geringerer Energieverbrauch.

##### Betriebsdaten

In einer Beispielanlage zur Käseherstellung wurde im Januar 1994 ein Projekt zur Verringerung des Energieverbrauchs begonnen. Vor Beginn des Projektes wurde der Käse zur Reifung bei 12 °C gelagert. Die Temperatur wurde dann auf 15 °C erhöht. Die zirkulierende Luft wurde angefeuchtet und durch Ionisierung vor dem Eintritt in den Lagerraum von Staub und Mikroorganismen befreit. Die neue Anlage ermöglicht eine Erhöhung der Temperatur auf 16 °C bei einer relativen Luftfeuchtigkeit von 85%. Die Energieeinsparung wurde

mit 272.000 kWh bzw. 85.000 m<sup>3</sup> Erdgas pro Jahr angegeben. Weiterhin wurde von einer Verkürzung der Reifezeit um 50%, einer Verbesserung der Produktqualität und einem Rückgang des Verbrauchs an Kunststoffen und Fungiziden berichtet.

### Anwendbarkeit

In allen Anlagen zur Käseherstellung anwendbar. Die Reifung bei höheren Temperaturen ist aufgrund des gewünschten Geschmacks, der Produktqualität und Produktstabilität nur eingeschränkt anwendbar.

### Wirtschaftlichkeit

In der Beispielanlage wurden erhebliche Einsparungen bei den Lohnkosten, der Wartung und dem Materialverbrauch zur Reinigung des Belüftungssystems erreicht. Die Amortisationszeit beträgt etwa zwei Jahre.

### Anlass für die Umsetzung

Senkung der Energiekosten.

### Beispielanlagen

Eine Lagerhalle für Käse in den Niederlanden.

### Referenzliteratur

[143, CADDET Energy Efficiency, 1997, 222, CIAA-Federalimentare, 2003, 239, CIAA-EDA, 2003]

## **4.7.5.15 Speiseeis**

### **4.7.5.15.1 Wärmerückgewinnung aus der Pasteurisation bei der Herstellung von Speiseeis**

#### Beschreibung

Aus dem Pasteurisationsverfahren für Speiseeis können Wärme und Wasser rückgewonnen werden. Der Eismix wird mit einer Temperatur von 60 °C in den Pasteurisator geleitet und dort auf 85 °C erhitzt; danach wird das Eis vor dem Reifen auf 4 °C abgekühlt. Die Abkühlphase besteht aus zwei Stufen. In der ersten Stufe wird das Speiseeis mittels regenerativer Wärmetauscher auf 70 °C abgekühlt. In der zweiten Stufe wird Kühlwasser benutzt, um eine weitere Abkühlung auf etwa 20 °C zu erreichen. Die Endtemperatur von 4 °C wird durch Kühlung mit Eiswasser erreicht.

Die Wärme, die während der zweiten Stufe aus dem Eismix an das Wasser abgegeben wird, kann zur Vorwärmung von Wasser für unterschiedliche Zwecke, meistens für Reinigungsverfahren, verwendet werden. Dazu ist eine Reihe von Lagertanks für das heiße Wasser erforderlich.

#### Erreichbare Umweltvorteile

Geringerer Energie- und Wasserverbrauch.

#### Medienübergreifende Effekte

Die hygienische Beschaffenheit des Wassers muss überprüft werden, da Lecks in den Platten des Wärmetauschers eine Verunreinigung des Wassers mit dem Produkt zur Folge haben können.

#### Betriebsdaten

In einer Beispielanlage zur Herstellung von Speiseeis wird die Wärme aus der zweiten Kühlstufe dazu genutzt, etwa 25% des in der gesamten Anlage verwendeten Wassers vorzuwärmen. Durch Wärmerückgewinnung erhält man Heißwasser mit einer Temperatur von etwa 70 °C. Die durchschnittliche Einlauftemperatur des Kühlwassers beträgt 10 °C, die entsprechende Menge der rückgewonnenen Wärme beträgt 7.600 GJ/Jahr bzw. etwa 14% des Energieverbrauchs der Anlage. Das Heißwasser wird für die CIP-Reinigung eingesetzt, und die eingesparte Wassermenge entspricht etwa 1.000 l pro t hergestellten Speiseeismixes.

#### Anwendbarkeit

In neuen und bereits bestehenden Anlagen anwendbar. Für die Wasserlagertanks wird Platz benötigt.

#### Wirtschaftlichkeit

Geringere Kosten für Energie und Wasser.

#### Beispielanlagen

Mindestens eine Anlage zur Herstellung von Speiseeis in Schweden.

Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001]

**4.7.5.16 Wiederverwendung und Wiederverwertung von Wasser zur Reinigung in Molkereien**

Weitere Information zur Reinigung siehe Abschnitt 4.3.

Beschreibung

Kühlwasser, Kondensate aus Verdampfungs- und Trocknungsverfahren, Permeate, die bei Membrantrennverfahren anfallen, und Reinigungswasser können in Molkereien wiederverwendet werden.

In einigen Fällen muss bei der erneuten Verwendung des Wassers das Risiko einer Kreuzkontamination berücksichtigt werden, z. B. bei den Starteransätzen in der Käseherstellung.

Wird eine unnötige Kontamination des Kondensats vermieden, so gibt es mehr Möglichkeiten für die Wiederverwendung des Wassers, manchmal ohne irgendeine Behandlung, je nach beabsichtigter Verwendung. Das sauberste Kondensat kann als Kesselspeisewasser geeignet sein. Tabelle 4.107 zeigt Möglichkeiten der Wiederverwendung von Wasser in Molkereien.

| <b>Ver-<br/>wendung<br/>Wieder-<br/>verwendung</b>  | <b>Reinigungs-<br/>lösung aus<br/>der CIP-<br/>Reinigung</b> | <b>Letztes<br/>CIP-<br/>Spül-<br/>wasser</b> | <b>Kondensat</b> | <b>Permeat aus<br/>der<br/>Umkehrosiose</b> |
|---|--|--|------------------|---|
| Reinigung der Fahrzeuge von außen   | 1  | 1  | 1                | 1   |
| Reinigung von Kästen  | 2  | 1  | 1                | 1   |
| Manuelle Reinigung der Außenseite von Geräten   | 3  | 3  | 1                | 1   |
| Vorspülung bei der CIP-Reinigung  | 2  | 1  | 1                | 1   |
| Hauptwasser-versorgung bei der CIP-Reinigung  | 3  | 3  | 3                | 1   |
| Letztes CIP-Spülwasser  | NEIN   | 3  | 3                | 3   |
| Spülung der Produktleitungen mit Wasser   | NEIN   | 3  | 3                | 3   |
| 1. Direkte Wiederverwendung<br>2. Wiederverwendung nach Aussieben der Feststoffe<br>3. Wiederverwendung nach intensiver Behandlung, z. B. Membrantrennverfahren und/oder Desinfektion |  |  |                  |   |

**Tabelle 4.107: Möglichkeiten der Wiederverwendung von Wasser in Molkereien**

Erreichbare Umweltvorteile

Geringerer Wasserverbrauch, geringeres Abwasseraufkommen und geringere Verschmutzung des Abwassers. Es können wertvolle Nebenprodukte hergestellt und die Entstehung von Abfall verringert werden.

Betriebsdaten

Es wird berichtet, dass in einer Beispielmolkerei in Großbritannien, die pro Tag 2.500 t Milch verarbeitet, das gesamte Kondensat aus den Verdampfern aufgefangen, mit Umkehrosiose behandelt und desinfiziert wird, bevor es als Wasser zum Reinigen benutzt wird. Die Menge an Wasser, die täglich verdampft, liegt im Bereich von 2.000 m<sup>3</sup>. Etwa 10% der ankommenden Flüssigkeit können nicht weiterverwendet werden und werden zur

Abwasserbehandlung geleitet. Das Unternehmen hat das Ziel, den Trinkwasserverbrauch der Anlage auf Null zu senken. Vor der Behandlung wird das warme Kondensat zur Vorwärmung der einströmenden Milch verwendet.

Durch den Einsatz von Membranverfahren bei der Molkeverarbeitung können wertvolle Nebenprodukte, Molkenproteinkonzentrat und Lactosekonzentrat hergestellt werden. Wird ein Umkehrosmoseverfahren eingesetzt, entsteht entmineralisiertes Wasser, das sich als Kesselspeisewasser oder zur CIP-Reinigung von Membranen eignet. Abbildung 4.68 zeigt ein Fließbild einer Membranverarbeitungsanlage in der Käseherstellung.

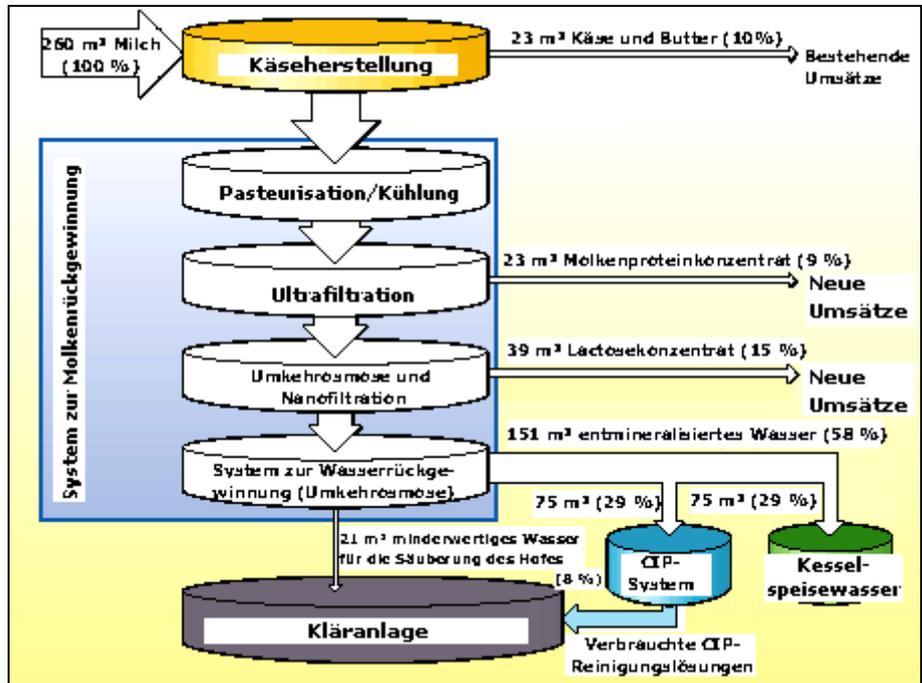


Abbildung 4.68: Fließbild einer Membranverarbeitungsanlage

Anwendbarkeit

In allen Molkereien anwendbar.

Anlass für die Umsetzung

Geringerer Trinkwasserbedarf und die Herstellung wertvoller Nebenprodukte.

Beispielanlagen

In mindestens einer milchproduzierenden Molkerei in Großbritannien wird behandeltes Kondensat aus dem Verdampfer zur Reinigung verwendet. In mindestens einer käseherstellenden Molkerei in Großbritannien wird entmineralisiertes Wassers mittels Umkehrosmose produziert und als Kesselspeisewasser oder zur CIP-Reinigung von Membranen verwendet.

Referenzliteratur

[52, Envirowise (UK), 2000, 94, Environment Agency of England and Wales, 2002]

**4.7.5.17 Wiederverwendung von warmem Kühlwasser zur Reinigung**

Beschreibung

Im Molkereisektor wird das meiste Wasser für die Reinigungszwecke benötigt, und deshalb bestehen in diesem Bereich auch große Einsparmöglichkeiten. Viele Verfahren in der Molkerei beinhalten die Kühlung mit kaltem Wasser in Wärmetauschern, wobei erwärmtes Kühlwasser entsteht. Gewöhnlich wird dieses erwärmte Kühlwasser aus dem Prozess für Reinigungszwecke, hauptsächlich zur Reinigung von Milchtankwagen, wiederverwendet. Erwärmtes Kühlwasser kann generell für die Reinigung in der Anlage verwendet werden, unabhängig von seiner Temperatur. In der milchverarbeitenden Industrie kann Wasser, das wärmer ist als 50 °C, für die Reinigung von Milchtankwagen, für manuelle Reinigungsgänge oder für die CIP-Reinigung von Geräten wiederverwendet werden.

Erreichbare Umweltvorteile

Die Einsparungen an Wasser und Energie sind abhängig davon, wieviel wiederverwendbares warmes Kühlwasser genutzt wird und was es für eine Temperatur hat.

Betriebsdaten

Wird dieses Wasser für die Reinigung von Oberflächen eingesetzt, die möglicherweise mit Produkten in Berührung kommen, so ist die hygienische Beschaffenheit des warmen Kühlwassers von größter Bedeutung. Im Allgemeinen ist die Qualität gut, vorausgesetzt, das Wasser enthält keine Produktpuren, die durch Lecks in den Anlagen hineingeraten sind. Normalerweise wird das Wasser bis zur weiteren Verwendung für einige Zeit in einem isolierten Puffertank gelagert. Eine Möglichkeit, Hygienrisiken so weit wie möglich zu minimieren, ist die Behandlung des Wassers mit UV-Strahlen. Der Einsatz von UV-Strahlen und andere Techniken sind in den Abschnitten 4.5.4.8, 4.5.4.8.1 und 4.5.4.8.2 beschrieben.

Eine nordische Beispielmolkerei gab an, den Wasserverbrauch um etwa 2% verringert zu haben.

Anwendbarkeit

Die Wiederverwendung von Kühlwasser ist in neuen und bereits bestehenden Anlagen möglich. Der Platzbedarf für die Warmwassertanks kann bei bestehenden Anlagen eine Einschränkung sein. Die Verwendung des Wassers hängt auch davon ab, welche Chemikalien gegebenenfalls vorher für die Reinigung verwendet wurden.

Wirtschaftlichkeit

Die Kosten stehen im Zusammenhang mit der Installation der Ausstattung, die erforderlich ist, um das warme Kühlwasser für die Reinigung wiederzuverwenden, d. h. ein Lagertank und Leitungen zum Sammeln und Verteilen des Wassers.

Anlässe für die Umsetzung

Geringere Kosten für Energie und Wasser.

Beispielanlagen

Je eine Molkerei in Schweden und in Finnland.

Referenzliteratur

[42, Nordic Council of Ministers, et al., 2001]

**4.7.5.18 Prozessintegriertes Umweltmanagement in einer Molkerei – Fallstudie**Beschreibung

Eine Beispielmolkerei verarbeitet 1,2 Mio. l Milch pro Woche und produziert etwa 200 t Joghurt und 15 t Hüttenkäse pro Woche. Die restliche Milch wird zu pasteurisierter und UHT-Milch und -Sahne verarbeitet. Das Abwasser wird in eine kommunale Kläranlage geleitet.

Der Betreiber der Anlage entschied sich für eine Aufrüstung der betriebseigenen Kläranlage, die eine Sedimentation für einen Teil des Abwassers vor der Einleitung ins Meer beinhaltet. Die geschätzten Kosten für die Abwasserbehandlung wurden dadurch halbiert, dass prozessintegrierte Techniken zur Minimierung der Entstehung und Kontamination von Abwasser eingeführt und angewandt wurden.

Alle Mitarbeiter waren an der Durchführung der folgenden Maßnahmen beteiligt:

- bei der Herstellung von Hüttenkäse wurde die Molke bereits als Tierfutter gesammelt (siehe Abschnitt 4.7.5.14.4), es wurde jedoch die Anzahl der zur Verfügung stehenden Tanks erhöht, um das Waschwasser des Käsebruchs und Joghurtreste aufzufangen; außerdem wurde jeder Tank mit einem Höchstfüllstandsalarm ausgerüstet (siehe Abschnitt 4.1.8.3)
- die Bögen des Leitungssystems für die Joghurtherstellung wurden auf einen Winkel von 135° gebracht, um das selbständige Abfließen zu verbessern (siehe Abschnitt 4.1.3.1)
- beim Entleeren der Joghurtbottiche wurden die Abtropfzeiten um 5 Minuten verlängert
- Für alle Joghurtbottiche wurde die Impulsspülung eingeführt, wobei das Spülwasser als Tierfutter gesammelt wird (siehe Abschnitt 4.1.7.7)
- die Forderung, das gesamte Spülwasser aus der Joghurt- und Obstverarbeitung innerhalb der Molkerei zur Verwendung als Tierfutter zu sammeln, wurde strenger durchgesetzt (siehe Abschnitte 4.1.7.6 und 4.1.7.7).

### Erreichbare Umweltvorteile

Geringere Abwassermenge und geringere Verschmutzung des Abwassers, z. B. CSB.

### Betriebsdaten

Die kommunale Kläranlage war bereit, 1.130 kg CSB/Tag und ein Volumen von 450 m<sup>3</sup>/Tag zu akzeptieren, aber beide Werte wurden häufig überschritten. Der CSB-Wert des Abwassers wurde auf 450 kg/Tag reduziert und die eingeleiteten Volumen auf den genehmigten Wert von rund 420 m<sup>3</sup>/Tag gebracht.

### Wirtschaftlichkeit

Die Kosten für die Abwasserbehandlung lagen bei 125.000 EUR/Jahr anstelle der erwarteten 500.000 EUR/Jahr, und die Investitionskosten dafür waren nur gering.

### Referenzliteratur

[1, CIAA, 2002]

## 4.7.6 Stärke

### 4.7.6.1 Verwendung/Wiederverwendung von Stärkewaschwasser im Gegenstrom

#### Beschreibung

Das Gegenstromprinzip ist ein grundlegendes Verfahren, das im Bereich der Lebensmitteltechnologie und der Chemietechnik Anwendung findet. Es bedeutet, dass zwei Ströme durch den gleichen Bereich geführt werden, jedoch in einander entgegengesetzter Richtung.

Im Bereich der Nahrungsmittelproduktion wird das Gegenstromverfahren in der Regel so angewandt, dass Trinkwasser erst am Ende der Produktionslinie zur Behandlung des Endproduktes eingesetzt wird, d. h. im üblicherweise saubersten Bereich des Prozesses. Das Wasser aus dieser Verarbeitungsstufe ist relativ sauber und kann für eine andere Stufe des Verarbeitungsverfahrens eingesetzt werden, für die das Wasser eine ausreichende Sauberkeit hat; das ist gewöhnlich früher im Prozess, d. h. die Fließrichtung des Wassers ist der des Produkts entgegengesetzt, sodass das Endprodukt nur mit frischem Trinkwasser in Berührung kommt.

Gegenströme werden für Waschverfahren eingesetzt.

Der Vorteil des Gegenstromverfahrens liegt darin, dass die für eine bestimmte Produktqualität erforderliche Wassermenge – und folglich auch die daraus resultierende Abwassermenge – im Prinzip so weit wie möglich verringert.

#### Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs und folglich des entstehenden Abwasservolumens.

#### Betriebsdaten

Diese Technik kann kontinuierlich oder chargenweise eingesetzt werden.

In der Praxis ist es üblich, den rohen Stärkeschlamm im Gegenstrom zu waschen, bevor dieser zwecks Herstellung raffinierter Stärke entwässert und getrocknet wird. Die Stärke wird im Gegenstrom mit Trinkwasser in einer Anordnung von 4-6 Zentrifugen gewaschen. An einem Ende der Linie wird rohe Stärke zugeführt und Prozesswasser abgeleitet, am anderen Ende wird frisches Trinkwasser zugeführt und raffinierte Stärke abgeleitet. Mit dem Gegenstromsystem wird wesentlich weniger Wasser benötigt als bei wiederholtem Waschen mit frischem Trinkwasser oder bei Zusatz von frischem Trinkwasser in jeder Stufe.

#### Anwendbarkeit

Anwendbar, wenn mehrere Waschstufen erforderlich sind, bei denen zunehmend sauberes Wasser benötigt wird.

#### Anlass für die Umsetzung

Verringerung des Wasserverbrauchs.

#### Beispielanlagen

Zahlreiche Anlagen, in denen Stärke aus Mais, Weizen oder Kartoffeln hergestellt wird.

Referenzliteratur

[182, Germany, 2003, 208, CIAA-AAC-UFE, 2003]

**4.7.7 Zucker****4.7.7.1 Trocknung der Zuckerrübenschnitzel**

Nachdem der Zucker aus den frischen Rübenschnitzeln extrahiert wurde, werden die Schnitzel gepresst. Wenn sie nach dem Pressen einen Feststoffgehalt von 12-17 % haben, werden sie Nassschnitzel genannt.

Wenn sie nach dem Pressen einen Feststoffgehalt von 18-34 % haben, werden sie Pressschnitzel genannt.

Sowohl Nass- als auch Pressschnitzel können als Tierfutter verkauft werden, z. B. als süßes Futter für Rinder. Dies erfolgt normalerweise nach dem Trocknen der Schnitzel.

Trockenschnitzel erhält man durch Trocknen der Schnitzel auf einen Feststoffgehalt von 86-92 %. Aus 100 kg Zuckerrüben kann man etwa 5,6 kg Trockenschnitzel mit einem Feststoffgehalt von 90 % erzeugen. Wenn man den Zuckerrübenschnitzeln vor dem Trocknen 1-3 % Melasse (bezogen auf das Gewicht der Schnitzel) zusetzt, erhält man Melasseschnitzel mit unterschiedlichem Zuckergehalt, z. B. 9-30 %. Neben dem Zuckergehalt unterliegen auch die enthaltenen Mengen an in Salzsäure unlöslichen Stoffen, Calcium und Asche den Futtermittelvorschriften der einzelnen Länder.

Die Trocknung der Schnitzel erfolgt in der Regel durch Konvektion, z. B. durch Trocknung mit Hilfe von Luft, Rauchgas oder Dampf. Bei der Trocknung mit Luft oder Rauchgas wird das zur Trocknung benutzte Gas erhitzt und dann mit den Rübenschnitzeln in Kontakt gebracht. Warme, trockene Luft kann bis zur Sättigung Wasserdampf aufnehmen. Im Trocknungsprozess finden gleichzeitig Wärme- und Stoffübertragung statt. Im ersten Trocknungsabschnitt bleibt die Trocknungsrate praktisch konstant. Während dieser Zeit verdunstet die ungebundene Flüssigkeit von der Oberfläche der Feststoffe und wird vom Trocknungsmedium abtransportiert. Fällt der Feuchtigkeitsgehalt unter einen kritischen Wert, trocknet die Oberfläche der Feststoffe aus, und innerhalb der porösen Feststoffe findet eine weitere Verdunstung statt. Die Trocknungsgeschwindigkeit verringert sich mit fallendem Feuchtigkeitsgehalt. Diese Phase wird als der zweite Trocknungsabschnitt bezeichnet. Die Restfeuchte in den Feststoffen ist durch Sorption an diese gebunden. Die Trocknungsgeschwindigkeit nimmt mit fallendem Feuchtigkeitsgehalt schnell ab und geht bei Annäherung an das hygroskopische Gleichgewicht gegen null. Der Bereich zwischen dem maximalen hygroskopischen Feuchtigkeitsgehalt und dem Gleichgewichtswert wird als dritter Trocknungsabschnitt bezeichnet. Ein umso geringerer restlicher Feuchtigkeitsgehalt im Trocknungsgas ist erforderlich, je niedriger die Restfeuchte der Schnitzel sein soll.

Bei der Trocknung mit Dampf sind die Anforderungen an das Trocknungsgas ähnlich. Hohe Feststoffgehalte in dem zu trocknenden Material erfordern einen stark überhitzten Dampf, entsprechend der niedrigen relativen Luftfeuchtigkeit.

In den Abschnitten 4.7.7.1.1 - 4.7.7.1.5 ist die Trocknung von Zuckerrübenschnitzeln in Anlagen zur Zuckerherstellung beschrieben. Die Entscheidung, ob die Zuckerrübenschnitzel getrocknet werden, hängt von verschiedenen Faktoren ab, z. B. von der Frage, ob es in der Nähe eine Verwertung der Nassschnitzel beispielsweise als Tierfutter gibt. Die Lagerung von Nassschnitzeln kann Geruchsprobleme aufwerfen, und der Transport von Nassschnitzeln ist teuer. In verschiedenen europäischen Ländern, z. B. in Frankreich, können die Schnitzel in normalerweise zu landwirtschaftlichen Betrieben gehörenden Anlagen getrocknet werden, die nicht direkt an der Zuckerherstellung beteiligt sind.

**4.7.7.1.1 Niedertemperaturtrocknung von Zuckerrübenschnitzeln**Beschreibung

Bei der zweistufigen Trocknung von Zuckerrübenschnitzeln kann die Niedertemperaturtrocknung der Hochtemperaturtrocknung vorgeschaltet sein. Bei der Niedertemperaturtrocknung von Zuckerrübenschnitzeln werden große Mengen an Trocknungsgas, z. B. Luft oder Rauchabgase<sup>33</sup>, die eine Einlasstemperatur von etwa 50 °C haben, gesättigt. Die Austrittstemperatur beträgt 25-30 °C. Für die Niedertemperaturtrocknung werden Bandtrockner eingesetzt.

<sup>33</sup> Anm. d. UBA-Bearb.: Meist aus Energie- oder Dampferzeugeranlagen der Zuckerindustrie vorgelagerten Einrichtungen.

### Erreichbare Umweltvorteile

Das durch die Trocknung der Schnitzel hergestellte Tierfutter kann länger gelagert werden als feuchtes Futter.

### Medienübergreifende Effekte

Es wird Energie verbraucht. Staub und Geruch werden an die Luft abgegeben. Bei Verwendung von Rauchgasen wird  $\text{NO}_x$  emittiert. Das erforderliche Gasvolumen ist bei der Niedertemperaturtrocknung etwa dreifach so hoch wie bei der Hochtemperaturtrocknung (siehe Abschnitt 4.7.7.1.2).

### Betriebsdaten

Tabelle 4.108 enthält Beispiele für die Abluftwerte bei Niedertemperaturtrocknung und bei Hochtemperaturtrocknung von Zuckerrübenschnitzeln.

| Parameter des Trocknungsgases  |        | Niedertemperaturtrocknung         |          |            | Hochtemperaturtrocknung          |          |            |
|--|--------|-----------------------------------|----------|------------|----------------------------------|----------|------------|
|  |        | Einlass                           | Austritt | $\Delta Y$ | Einlass                          | Austritt | $\Delta Y$ |
| Temperatur   | °C     | 50                                | 25       |            | 750                              | 102      |            |
| Relative Feuchtigkeit des Gases  | %      | 9,0                               | 88,6     |            | *                                | 33,1     |            |
| Wasserdampfbeladung  | kg/kg  | 0,0070                            | 0,0181   | 0,0111     | 0,0366                           | 0,3508   | 0,3142     |
| Enthalpie der feuchten Luft in Relation zu trockener Luft                                      | kJ/kg  | 68,8                              | 71,1     |            | 983,2                            | 1.049,8  |            |
| Enthalpie der feuchten Luft in Relation zu trockener Luft                                      | kWh/kg | 0,019                             | 0,020    |            | 0,273                            | 0,292    |            |
| Verhältnis Luft/verdampftes Wasser   | kg/kg  | $1/\Delta Y = 0,0111^{-1} = 89,9$ |          |            | $1/\Delta Y = 0,3142^{-1} = 3,2$ |          |            |
| * Nicht definiert, da kritische Temperatur überschritten<br>$\Delta Y$ : Steigung der Funktion |        |                                   |          |            |                                  |          |            |

**Tabelle 4.108: Charakteristische Nieder-/Hochtemperaturtrocknung von Zuckerrübenschnitzeln**

### Anwendbarkeit

Für die Trocknung von Rübenschnitzeln in der Zuckerindustrie anwendbar.

### Anlass für die Umsetzung

Das durch die Trocknung der Schnitzel hergestellte Tierfutter kann länger gelagert werden als feuchtes Futter.

### Beispielanlagen

Wird in zwei Anlagen in Deutschland in Verbindung mit der Hochtemperaturtrocknung eingesetzt.

### Referenzliteratur

[65, Germany, 2002]

## 4.7.7.1.2 Hochtemperaturtrocknung von Zuckerrübenschnitzeln

### Beschreibung

Bei der Hochtemperaturtrocknung wird das Trocknungsgas, z. B. Luft oder Rauchgase, durch direkte Befuerung auf eine Temperatur von bis zu 950 °C erhitzt und dann im Trockner durch die Verdampfung von Wasser aus den Schnitzeln auf etwa 100 °C abgekühlt. Für das Trocknen von Pressschnitzeln werden Trommel-trockner mit vorgeschalteter Feuerung im Gleichstrom betrieben.

### Erreichbare Umweltvorteile

Das durch die Trocknung der Schnitzel hergestellte Tierfutter kann länger gelagert werden als feuchtes Futter.

### Medienübergreifende Effekte

Es wird Energie verbraucht. Es fällt Abwasser an. Staub und Geruch werden an die Luft abgegeben. Bei Verwendung von Rauchgasen werden  $\text{NO}_x$ , CO und organische Verbindungen emittiert.

### Betriebsdaten

Siehe auch Abschnitt 4.7.7.1.5.

Die Wärmemenge, die für das Verdampfen von 1 kg Wasser benötigt wird, ist abhängig vom Gradienten zwischen Eintritts- und Austrittstemperatur an der Trommel. Je höher die Temperatur des Verbrennungsgases beim Eintritt in die Trommel ist, umso größer ist der thermische Wirkungsgrad der Anlage. Hochtemperaturtrocknungen finden in der Regel bei Temperaturen bis zu 750 °C statt; eine Ausnahme ist das Vereinigte Königreich, wo bei 950 °C getrocknet wird. Es wird berichtet, dass hierbei die Energieeffizienz 15-18% höher ist als bei einer Trocknung mit 750 °C. Allerdings können extrem hohe Eintrittstemperaturen zu einer starken Verzunderung der Innenteile und zur Verbrennung des zu trocknenden Materials führen. Für Eintrittstemperaturen von 600 °C werden etwa 0,972 kWh (3.500 kJ) pro Kilogramm zu verdampfenden Wassers benötigt. In den Trommeln verdampfen pro Kubikmeter Trommelinhalt 150-180 kg Wasser pro Stunde. Am Ende des Prozesses beträgt die Temperatur des Trocknungsgases etwa 100 °C. Das zu trocknende Material kommt während des Trocknungsprozesses auf eine Temperatur von 60-70 °C.

Das Trocknungsgas kann eine Mischung aus Feuerungsabgas, das bei der Verbrennung des Brennstoffs in der Direktfeuerungsanlage entsteht, rückgeführtem Rauchgas aus dem Trockner, Rauchabgas aus dem Kessel für die Dampferzeugung und einer geringen Menge Umgebungsluft sein, die aufgrund der Bauweise des Systems in die Trommel eingesaugt wird. Nur in Ausnahmefällen wird Kühlluft eingesetzt. Das Rauchabgas aus der Dampferzeugung ist neben den Melasseschnitzeln die einzige Verbindung zwischen der Trocknungseinheit und dem Rest der zuckerproduzierenden Anlage.

Im Trocknungsprozess macht das Feuerungsgas etwa 25% der Masse und etwa 75% der Energie des durchströmenden Gases aus. Das Rauchabgas aus der Dampferzeugung liefert etwa 70% der Masse der Rauchgase und 25% der Energie der Trocknungsgase.

Bei Verwendung von Rauchabgas wird  $\text{NO}_x$  freigesetzt. Der Gehalt an  $\text{NO}_x$  ist eine Funktion des Brennstofftyps, des Brennertyps, der primären, sekundären und tertiären Luftanteile und der Stelle, an der die rückgewonnenen Abgase wieder eingeleitet werden. Beispielsweise betrug der durchschnittliche  $\text{NO}_x$ -Gehalt im Abgas von fünf zuckerproduzierenden Anlagen in Deutschland, die Erdgas verwenden, 70 mg/Nm<sup>3</sup>, während er in 12 mit Heizöl betriebenen zuckerproduzierenden Anlagen bei 270 mg/Nm<sup>3</sup> lag. Die Emission organischer Verbindungen liegt bei 50-600 mg/Nm<sup>3</sup> und die CO-Emission bei 210-1.050 mg/Nm<sup>3</sup>. Nach der Behandlung im Zyklon betrug die Staubkonzentration in der Abluft in den fünf zuckerproduzierenden Anlagen, die Erdgas verwenden, etwa 35 mg/Nm<sup>3</sup>, während in zwei Fabriken, die ihre Kessel mit Kohle befeuern und für die Trocknung Heizöl/Erdgas einsetzen, die durchschnittliche Staubkonzentration bei etwa 82 mg/Nm<sup>3</sup> lag. Aus Deutschland wurden Emissionen von 50-60 mg/Nm<sup>3</sup> Nassstaub und 0,08 kg TOC/t geschnittener Rüben gemeldet; diese Werte wurden unter Referenzbedingungen bei 12 Vol% Sauerstoffgehalt der Luft gemessen. Der Staub in der Abluft eines Trockners hängt auch vom Feuchtigkeitsgehalt der getrockneten Schnitzel ab. Ein Feststoffgehalt von über 91% kann zu einer höheren Staubbelastung der Abluft führen. Der Feststoffgehalt muss allerdings über 86% liegen, da ein höherer Feuchtigkeitsgehalt die biologische Stabilität der Rübenschnitzel verringern kann.

Der wichtigste Umweltaspekt ist der Energieverbrauch. Der Energieverbrauch kann durch Reduzierung des Ausgangswassergehalts der Rübenschnitzel verringert werden. Beträgt der Feststoffgehalt der Schnitzel nach dem Pressen 25%, dann müssen im Trocknungsprozess 2,6 t Wasser pro t Trockenschnitzel verdampfen, damit ein Feststoffgehalt von 90% erreicht wird. Haben die gepressten oder vorgetrockneten Schnitzel einen Feststoffgehalt von 35%, dann müssen pro Tonne produzierter Trockenschnitzel nur noch 1,6 t Wasser verdampfen. Wenn weniger Wasser verdampft werden muss, wird auch weniger Luft oder Rauchgas benötigt und folglich fallen geringere Mengen Kondenswasser an. Dann müssen auch weniger Luft und Abfall behandelt werden.

Tabelle 4.108 enthält Beispiele für die Luftwerte bei Niedertemperaturtrocknung und bei Hochtemperaturtrocknung.

#### Anwendbarkeit

Hochtemperaturtrocknung ist das in Europa am häufigsten benutzte Verfahren. Es ist für die Trocknung von Rübenschnitzeln in der Zuckerindustrie anwendbar. Diese Technik kann unabhängig von der Betriebsmethode der zuckerproduzierenden Anlage und der Dampferzeuger eingesetzt werden.

#### Wirtschaftlichkeit

Siehe auch Abschnitt 4.7.7.1.5.

Dampftrocknung mit Wirbelschichttrockner und Zweistufentrocknung haben praktisch den gleichen Net Present Value (NPV), während die Hochtemperaturtrocknung um etwa 6% preiswerter ist. Wird die Berechnung jedoch auf Grundlage einer längeren betrieblichen Lebensdauer, d. h. 18 Jahre, für Trockner und Gasturbine erstellt, dann ist der NPV für die Dampftrocknung mit Wirbelschichttrockner der niedrigste, z. B. niedrigste Kosten.

### Anlass für die Umsetzung

Ausrüstungen und Verfahren stellen eine robuste und zuverlässige Technik dar. Es gibt eine Fülle an Erfahrung mit diesen Trocknungssystemen und dem Verfahren selbst. Das durch die Trocknung der Schnitzel hergestellte Tierfutter kann länger gelagert werden als feuchtes Futter.

### Beispielanlagen

Wird in den meisten Anlagen im Zuckersektor angewandt (siehe Abschnitt 4.7.7.1.5).

### Referenzliteratur

[65, Germany, 2002, 87, Ullmann, 2001]

### **4.7.7.1.3 Zweistufentrocknung der Zuckerrübenschnitzel**

#### Beschreibung

Für das Trocknen von Melasseschnitzeln werden die Schnitzel zunächst einer Niedertemperaturtrocknung in einem Bandtrockner unterzogen (siehe Abschnitt 4.7.7.1.1). Dann werden die Schnitzel mit der Melasse vermischt, und die Mischung wird in einem Trommeltrockner bei hoher Temperatur getrocknet (siehe Abschnitt 4.7.7.1.2). Die Niedertemperaturtrocknung ist die erste Stufe, bei der geringere Wärmeenergie aus der Hochtemperaturtrocknung und den Zuckerverarbeitungsverfahren genutzt wird.

#### Erreichbare Umweltvorteile

Weniger Energieverbrauch und geringere Luftverschmutzung als bei der Hochtemperaturtrocknung. Das durch die Trocknung der Schnitzel hergestellte Tierfutter kann länger gelagert werden als feuchtes Futter.

#### Medienübergreifende Effekte

Staub und Geruch werden emittiert. Bei Verwendung von Rauchgas werden NO<sub>x</sub>, CO und organische Verbindungen emittiert. Es fällt Abwasser an.

#### Betriebsdaten

Siehe auch Abschnitt 4.7.7.1.5.

Bei der Zweistufentrocknung können etwa 15 %<sup>34</sup> der Energie eingespart werden. Die meisten Bandtrockner arbeiten mit Heißluft von etwa 60 °C, die erwärmt werden kann von den Wärmeströmen aus der Verdampfungsstation und der Kristallisationseinheit der Zuckeranlage; andernfalls würden diese Wärmeströme als Abwärme in die Umgebung abgegeben und wären somit verloren.

Diese Nutzung der Sekundärenergie aus der Zuckerherstellung hat für die Trocknung der Zuckerrübenschnitzel dadurch einen Vorteil, dass Zuckerherstellung und Schnitzeltrocknung in der gleichen Produktionsanlage erfolgen. Dieses Verfahren wird besonders dann angewendet, wenn die Wärme nicht innerhalb der Zuckerproduktion wiederverwendet wird.

Das Abwasser, das durch die Kondensation der aus der Hochtemperaturtrocknung stammenden Dämpfe entsteht, kann entweder in die Kläranlage geleitet oder auf landwirtschaftlichen Nutzflächen ausgebracht werden.

#### Anwendbarkeit

Für die Trocknung von Melasseschnitzeln in der Zuckerindustrie anwendbar.

#### Wirtschaftlichkeit

Siehe auch Abschnitt 4.7.7.1.5.

Dampftrocknung mit Wirbelschichttrockner und Zweistufentrocknung haben praktisch den gleichen Net Present Value (NPV), während die Hochtemperaturtrocknung um etwa 6% preiswerter ist. Wird die Berechnung jedoch

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<sup>34</sup> Anm. d. Übers.: Im Original steht hier „30 %“.

auf Grundlage einer längeren betrieblichen Lebensdauer, d. h. 18 Jahre, für Trockner und Gasturbine erstellt, dann ist der NPV für die Dampftrocknung mit Wirbelschichttrockner der niedrigste, z. B. niedrigste Kosten.

#### Anlass für die Umsetzung

Das durch die Trocknung der Schnitzel hergestellte Tierfutter kann länger gelagert werden als feuchtes Futter.

#### Beispielanlagen

Dieses System gibt es nur in zwei Anlagen. Eine davon ist eine Versuchsanlage, und die andere hat eine sehr spezielle Konfiguration, z. B. wurde sie als Alternative zu einem normalen Fallwasserkreislauf installiert.

#### Referenzliteratur

[65, Germany, 2002]

### **4.7.7.1.4 Verdampfungstrocknung von Zuckerrübenschnitzeln**

#### Beschreibung

Die Trocknung wird mit übererhitztem Dampf durchgeführt. [...] <sup>35</sup>

#### Erreichbare Umweltvorteile

Geringere Staub- und Geruchsemissionen als bei der Hochtemperaturtrocknung. Da kein Rauchgas eingesetzt wird, wird auch kein NO<sub>x</sub> freigesetzt. Ein weiterer Vorteil ist der im Vergleich zur Hochtemperatur- und Zweistufentrocknung geringere Gesamtenergieverbrauch für die Trocknung. Die abgegebene Energie, z. B. Dampf, kann für die Extraktion des Zuckers wiederverwendet werden. Das durch die Trocknung der Schnitzel hergestellte Tierfutter kann länger gelagert werden als feuchtes Futter.

#### Medienübergreifende Effekte

Es fällt Abwasser an. Auch werden organische Verbindungen an Luft und Wasser abgegeben.

#### Betriebsdaten

Siehe auch Abschnitt 4.7.7.1.5.

Das geschlossene System der Verdampfungstrocknung hat den Vorteil, dass es das Entweichen gasförmiger Emissionen, z. B. Staub und Geruch, verringert. Allerdings ist das Entlüften der Gase für die Aufrechterhaltung der Wärmeübertragung in Wirbelschichttrocknern notwendig. Es wird berichtet, dass die Konzentration übelriechender Verbindungen in der Abluft von Wirbelschichttrocknern 5-50 Mal so hoch ist wie bei der Hochtemperaturtrocknung. Es wird weiter berichtet, dass Kondensatoren zur Verringerung der Geruchsemissionen eingesetzt werden können, aber diese Technik ist in diesem Dokument nicht beschrieben.

Bei Verdampfungstrocknern wird das Wasser in der Regel durch Kondensation aus der Abluft entfernt. Dabei fällt eine erhebliche Menge an Kondensat an. Zahlen für die Verdampfungstrocknung mittels Wirbelschichttrockner zeigen, dass pro Tonne Pressschnitzel 0,6-0,7 t Kondensat mit einer organischen Belastung von 0,20-0,25 kg TOC pro Tonne Pressschnitzel entstehen.

Es wird berichtet, dass diese Technik wegen der für die Verdampfungstrocknung der Zuckerrübenschnitzel erforderlichen Dampfmenge nur in Anlagen rentabel ist, die auch Zucker raffinieren.

#### Anwendbarkeit

Für die Trocknung von Rübenschnitzeln in der Zuckerindustrie anwendbar. Die Verdampfungstrocknung mit Wirbelschichttrocknern mit integriertem Dampfsystem kann in neuen Zuckerproduktionsanlagen eingesetzt werden. In bereits bestehenden Anlagen kann ein vollständiger Umbau der Energieerzeugung und Wärmeverteilung notwendig werden. Die Umrüstung beinhaltet den Umbau der Bereiche Dampf- und Stromerzeugung einschließlich der Überarbeitung der gesamten Einrichtungen zur Wärmeübertragung innerhalb der Anlage.

#### Wirtschaftlichkeit

Siehe auch Abschnitt 4.7.7.1.5.

Verdampfungstrocknung mit Wirbelschichttrockner und Zweistufentrocknung haben praktisch den gleichen Net Present Value (NPV), während die Hochtemperaturtrocknung um etwa 6% preiswerter ist. Wird die Berechnung

<sup>35</sup> Anm. d. UBA-Bearb.: Im Ausgangstext sind hier zwei Sätze inhaltlich falsch und wurden daher nicht übersetzt.

jedoch auf Grundlage einer längeren betrieblichen Lebensdauer, d. h. 18 Jahre, für Trockner und Gasturbine erstellt, dann ist der NPV für die Dampftrocknung mit Wirbelschichttrockner der niedrigste, z. B. niedrigste Kosten.

### Anlass für die Umsetzung

Kosten- und Energieeinsparungen. Das durch die Trocknung der Schnitzel hergestellte Tierfutter kann länger gelagert werden als feuchtes Futter.

### Beispielanlagen

Wird in sechs deutschen Zuckerfabriken eingesetzt (siehe Abschnitt 4.7.7.1.5).

### Referenzliteratur

[65, Germany, 2002]

#### **4.7.7.1.5 Vergleich zwischen Verdampfungs-, Hochtemperatur- und Zweistufentrocknung von Zuckerrübenschnitzeln**

##### Beschreibung

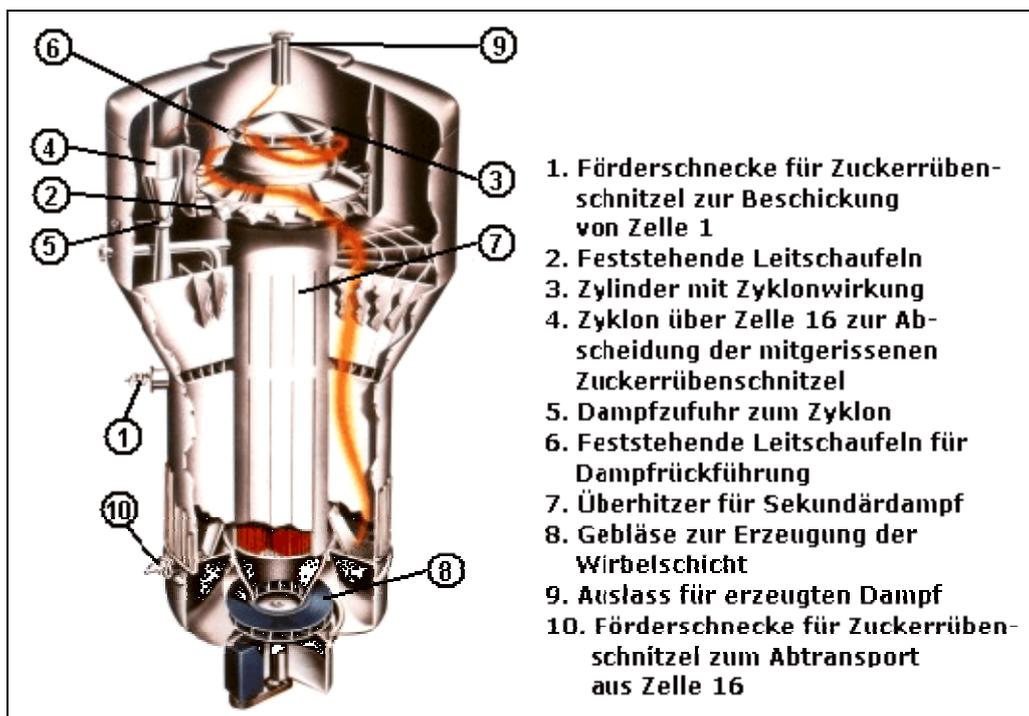
Es wurden drei Anlagen in Deutschland untersucht. Die erste Anlage arbeitet mit Verdampfungstrocknung und Wirbelschichttrocknern (siehe Abschnitt 4.7.7.1.4). Die zweite Anlage arbeitet mit Hochtemperaturtrocknung und Trommeltrocknern (siehe Abschnitt 4.7.7.1.2). Die dritte Anlage arbeitet mit dem Zweistufenverfahren (siehe Abschnitt 4.7.7.1.3).

In der ersten Anlage erfolgt Verdampfungstrocknung unter Verwendung von zwei Wirbelschichttrocknern. Das Trocknungsverfahren beginnt mit der Anlieferung der Rübenschnitzel aus der Presse. Der Dampf kommt mit 25 bar aus der Kesselhausturbine der zuckerproduzierenden Anlage. Am Ende des Trocknungsverfahrens werden die mit Melasse behandelten Rübenschnitzel zum Pelletieren und zu den Dampfrückgewinnungseinheiten transportiert. Die Einrichtungen zur Behandlung der Melasse sind Teil der Trocknungsanlage.

Zu Beginn werden die Wirbelschichttrockner über Fördereinrichtungen und Messeinrichtungen mit den aus der Presse kommenden Rübenschnitzeln beschickt. Die Schnitzel passieren eine Zellenradschleuse und einen Schneckenförderer und gelangen in die erste der 16 Zellen, die um den Überhitzer angeordnet sind. Ein Ventilator, neben der Zellenradschleuse das einzige bewegliche Teil des Wirbelschichttrockners, bläst überhitzten Dampf, der von dem aus der Dampfturbine abgezogenen Dampf überhitzt wurde, durch die perforierten Bodenplatten in die Zellen. Dadurch bleiben die Schnitzel in der Schwebelage und können leichter transportiert werden. Die Verdampfung der Flüssigkeit aus den Rübenschnitzeln findet in diesem Wirbelschichttrockner bei 3 bar statt. Der Satttdampf hat eine Temperatur von etwa 135 °C.

Die schwereren Teilchen im unteren Bereich bewegen sich durch die offenen Wände der Zellen 1 bis 16, während die leichteren Teilchen nach oben in den konischen Teil des Wirbelschichttrockners getrieben werden und von dort über schiefe Ebenen und Führungsschienen in Zelle 16 gelangen. Um die Staubteilchen abzutrennen, wird der umlaufende Dampf mit Leitschaufeln in den oberen Teil des Wirbelschichttrockners gelenkt, der die Form eines Zyklons hat. Die Teilchen sammeln sich an der Außenwand des Zyklons und werden dort mittels Ejektor in Zelle 16 transportiert. Das getrocknete Material gelangt von Zelle 16 über Schneckenförderer und Schleuse in einen Zyklon. Von dort aus passieren die getrockneten Schnitzel eine weitere Zellenradschleuse und gelangen in einen Melasseschneckenförderer, in dem die Melasse zugesetzt wird. Danach werden die Schnitzel über einen Aufbereitungsschneckenförderer zur Pelletierstation transportiert. Der aus den Trocknern abgezogene Dampf hat einen Druck von etwa 3 bar.

Der Trockner ist etwa 18 m hoch, wobei der untere Teil eine Höhe von 7,1 m und der obere Teil eine Höhe von 10,4 m aufweist. Das Gewicht beläuft sich auf 320 t. Abbildung 4.69 zeigt das Schema eines Wirbelschichttrockners, der für die Trocknung von Zuckerrübenschnitzeln eingesetzt wird.



**Abbildung 4.69:** Schematische Darstellung der Verdampfungstrocknung mit Wirbelschichttrocknern für die Trocknung von Zuckerrübenschnitzeln

Etwa 2/3 des gesamten Abdampfes wird in den Trocknern mit einem Druck von 25 bar eingesetzt und zu Prozessdampf mit einem Druck von 3 bar umgewandelt. Daher kann der Druck- oder Enthalpiegradient von 25 auf 3 bar nicht – wie sonst in Zuckerfabriken üblich – zur Erzeugung elektrischer Energie verwendet werden. Um den eigenen Anforderungen der Anlage zu genügen, und das betrifft auch den hohen Stromverbrauch der Trockner, ist es notwendig, eine andere Lösung als die sonst üblichen Dampfkraftwerke im Gegendruckbetrieb zu finden. Eine Möglichkeit ist die Nutzung einer Gasturbine, die für die Lieferung des maximalen zusätzlichen Strombedarfs ausgelegt ist. Da eine Gasturbine einen hohen Abgasverlust aufweist, ist der nachgeschaltete Dampferzeuger als Abgasheizkessel ausgelegt, der die thermische Energie aus den Abgasen der Gasturbine ausnutzt. Der Dampfkessel kann auch zusätzlich mit Heizöl befeuert werden, aber das mit Spezialbrennern ausgestatteten Feuerungssystem ermöglicht die Einhaltung der Abgaswerte der Betriebserlaubnis auch ohne die Notwendigkeit zusätzlicher Ausstattung für die Rauchgasreinigung. Abbildung 4.70 zeigt ein KWK- und Dampfsystem einer zuckerproduzierenden Anlage, in der Zuckerrübenschnitzel mit Dampf getrocknet werden.

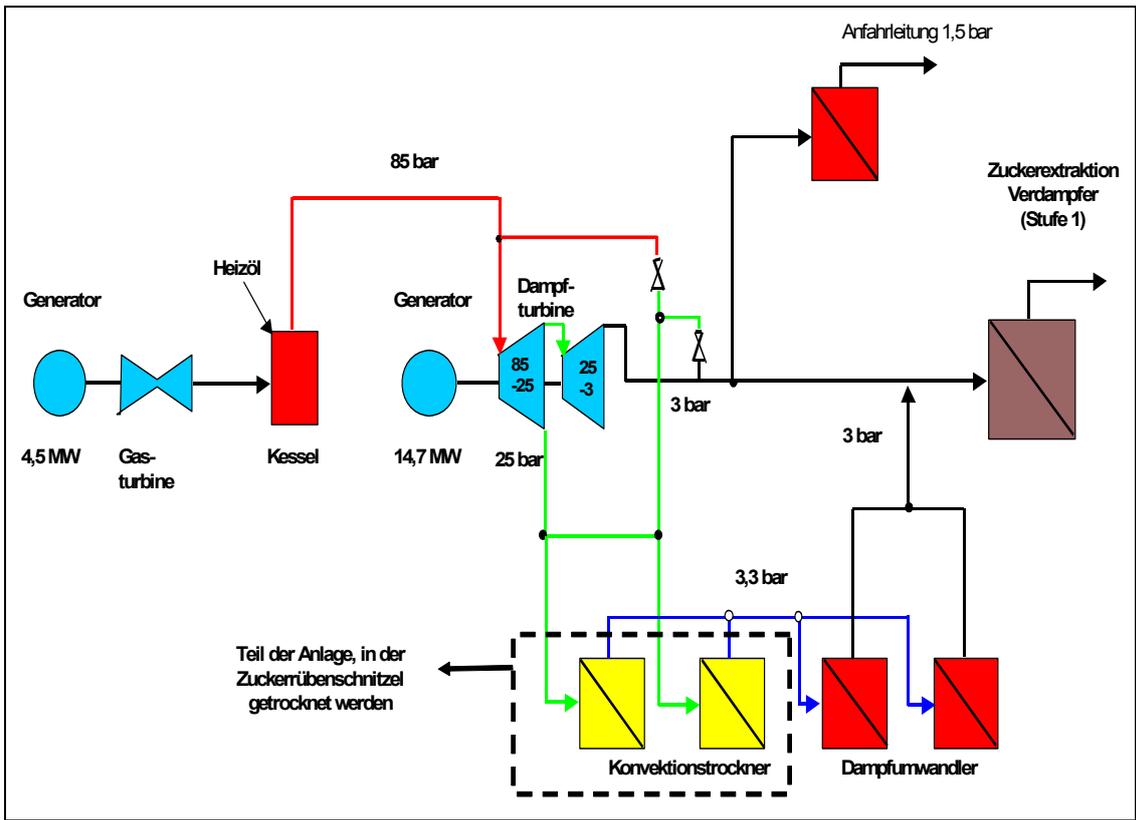


Abbildung 4.70: KWK- und Dampfsystem einer zuckerproduzierenden Anlage, in der Zuckerrübenschnitzel mit Dampf getrocknet werden.

Der Heißdampf, der einen Druck von 85 bar und eine Temperatur von 525 °C mit einem maximalen Massestrom von 110 t/h produziert, wird in die nachgeschaltete Gegendruck-Dampfturbine geführt. Die Turbine kann über ein Auslasssystem die erforderliche Dampfmenge mit einem Druck zwischen 11 und 25 bar zum Heizen der Verdampfungstrockners entnehmen. Die in den Trocknern freigesetzten Dämpfe werden in der Verdampfungsstation des Zuckerextraktionsverfahrens wiederverwendet. Die Dämpfe, die organische Substanzen enthalten, z. B. Säuren, werden durch einen nachgeschalteten Dampfumwandler geschickt und dann dazu genutzt, die erste Stufe der Verdampfungsstation zu erwärmen. Die nicht kondensierbaren Gase, die eine gewisse Menge Wasserdampf enthalten, werden vom Dampfumwandler in die Luft abgeleitet.

In der zweiten Anlage findet eine Hochtemperaturtrocknung statt. Die Pressschnitzel werden mit der Melasse vermischt und dann im Gleichstrom-Trommeltrockner unter Einsatz direkter Wärme getrocknet. Dazu wird eine Mischung aus Rauchgas aus der Feuerung und Rauchgas aus der Dampfbereitung genutzt. Ein weiterer Teil des Trocknungsmediums besteht aus der sogenannten Leck- oder Kühlluft. Da die stationäre Mischkammer und die rotierende Trommel laut Angaben nicht vollständig abgedichtet werden können, gelangt Luft ins Innere. Die Kühlluft, etwa 20% des Volumens des Trocknungsgases, ist außerdem erforderlich, um eine für den Transport der zu trocknenden Teilchen ausreichende Strömung zu erzeugen.

Abbildung 4.71 zeigt ein Fließbild und die Parameter für den Betrieb und den Energieverbrauch von Hochtemperaturtrocknern. Die Zahlen wurden aus Gründen der Vergleichbarkeit mit den in den zwei anderen Anlagen dieser Fallstudie angewandten Trocknungsmethoden standardisiert und vereinfacht. Für das Trocknen der Schnitzel, die in einem Werk mit einer Kapazität von 10.000 t/Tag (417 t/h) anfallen, würden etwa 46 t Wasser pro Stunde im Trockner verdampft werden. Wie aus Abbildung 4.71 ersichtlich, macht das Feuerungsgas etwa 30% des gesamten Gasvolumens und etwa 84% der eingetragenen Energie aus.

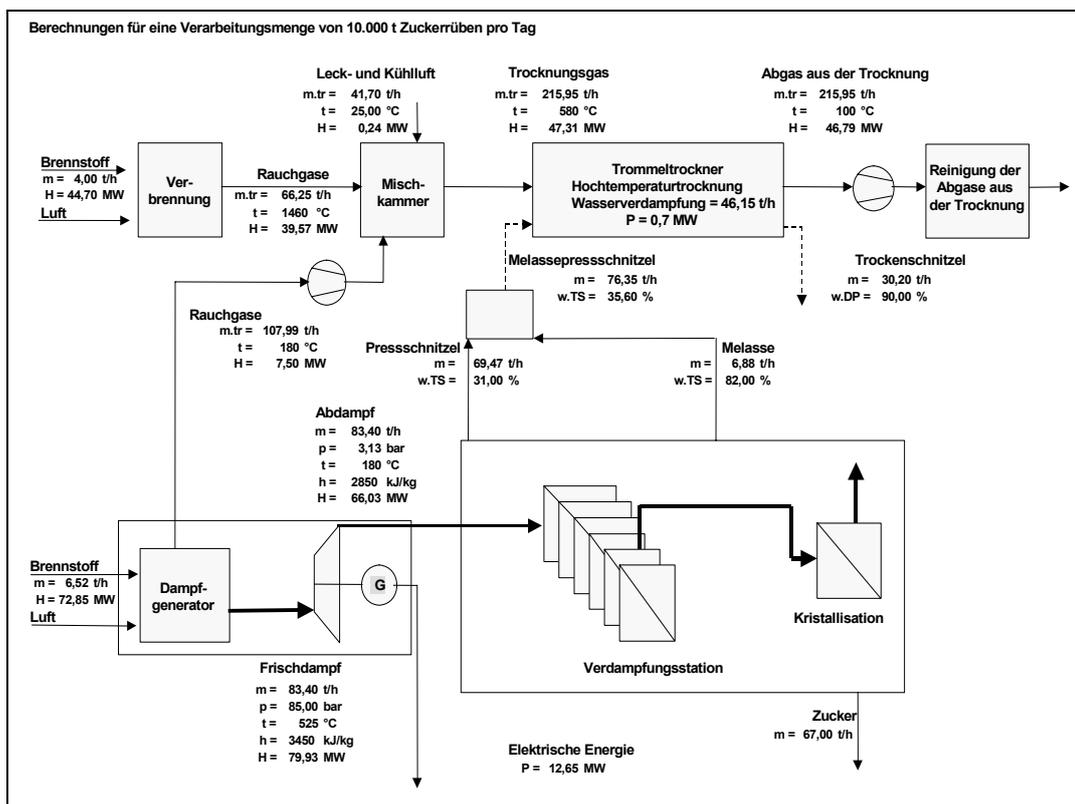


Abbildung 4.71: Hochtemperaturtrocknung von Zuckerrübenschnitzeln

Im dritten deutschen zuckerproduzierenden Betrieb werden die Rübenschnitzel im Zweistufenverfahren getrocknet. Zunächst werden die Rübenschnitzel auf einem nach dem Gegenstromprinzip arbeitenden Bandtrockner bei niedriger Temperatur getrocknet. Die Trocknungsluft für diesen Niedertemperaturtrockner wird mit Hilfe von Dämpfen, z. B. Wasserdampf, und Kondensaten aus den Verdampfungs- und Kristallisationsstationen der Zuckerproduktion erhitzt. Auf diese Weise kann Sekundärenergie genutzt und der Verbrauch an Primärenergie für die Hochtemperaturtrocknung verringert werden. Die Melasse wird mit den Schnitzeln vermischt, und in der zweiten Stufe erfolgt, ähnlich wie im vorherigen Beispiel, Hochtemperaturtrocknung.

Abbildung 4.72 zeigt das Fließbild eines zweistufigen Trocknungsverfahrens für Rübenschnitzel. Auch hier wurden die Werte auf eine Fabrik mit einer Kapazität von 10.000 t Rübenschnitzel/Tag (417 t/h) umgerechnet. In diesem Fall verdampfen bei der Hochtemperaturtrocknung etwa 62% des gesamten Wassers.

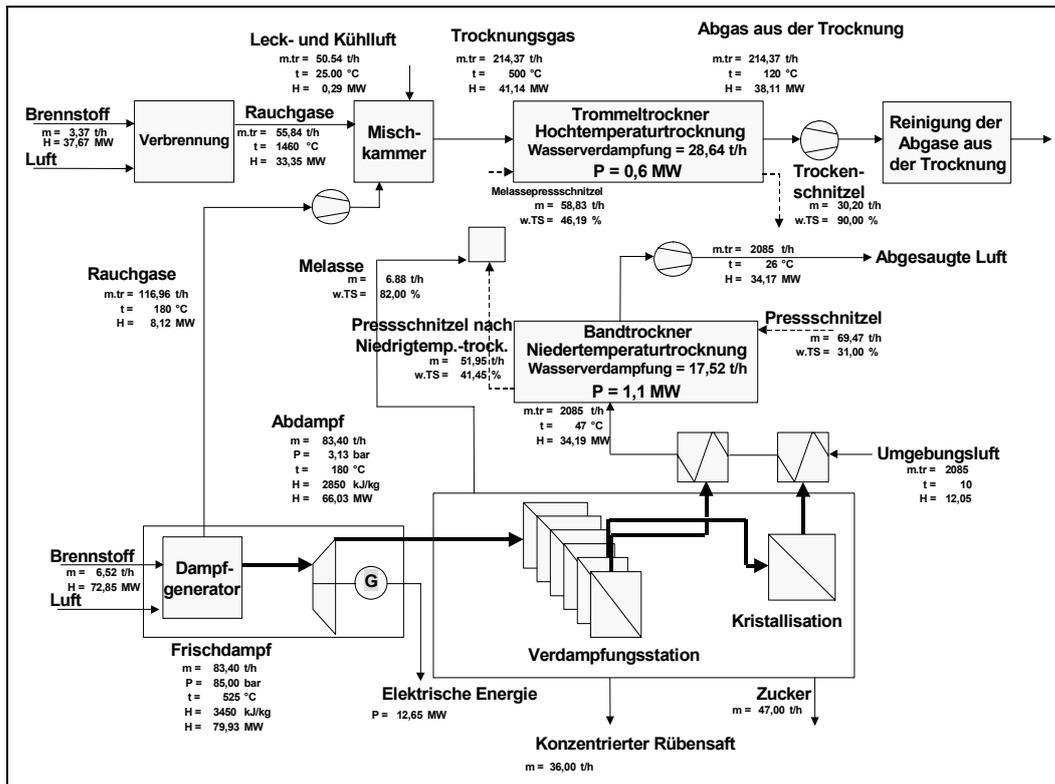


Abbildung 4.72:Zweistufentrocknung von Zuckerrübenschnitzeln

Erreichbare Umweltvorteile

Siehe Abschnitte 4.7.7.1.2, 4.7.7.1.3 und 4.7.7.1.4.

Medienübergreifende Effekte

Siehe Abschnitte 4.7.7.1.2, 4.7.7.1.3 und 4.7.7.1.4.

Betriebsdaten

Im Hinblick auf Energieaspekte für die drei oben beschriebenen Beispiele sind die Rahmenbedingungen der Anlagen gemäß Tabelle 4.109 auf eine Vergleichsanlage mit 10.000 t/Tag standardisiert.

|   |   |
|---|---|
| Verarbeitung von Zuckerrüben                | 10.000 t/Tag (417 t/h)                        |
| Dauer der Saison                            | 90 Tage/Jahr                                  |
| Masse der Pressschnitzel                    | 160 kg pro t verarbeiteter Rüben = 66,7 t/h   |
| Feststoffanteil der Pressschnitzel          | 31%   |
| Feststoffanteil der getrockneten Schnitzel  | 90%   |
| Dampfverbrauch der Zuckerfabrik             | 200 kg pro t verarbeiteter Rüben = 83,4 t/h   |
| Druck des Frischdampfes                     | 85 bar  |
| Temperatur des Frischdampfes                | 525 °C  |
| Heizwert des Brennstoffs                    | 11,2 kWh/kg (40195 kJ/kg)                     |
| Strombedarf der Zuckerfabrik ohne Trocknung | 10,4 MW = 24,96 kWh pro t verarbeiteter Rüben |

Tabelle 4.109: Standardisierte Rahmenbedingungen der drei Beispielanlagen in Deutschland

Bei der Standardisierung wurde auch davon ausgegangen, dass während der Zuckerrübensaison der gesamte konzentrierte Saft kristallisiert wird. Weiterhin wurde die Verwendung der folgenden technischen Anlagen zugrunde gelegt:

- Dampfgenerator mit 85 bar und 525 °C
- entsprechende Gegendruckturbine
- 3 bar Gegendruck zur Versorgung der Verdampferstation oder 3 bar Gegendruck und 25 bar Extraktionsdruck zur Versorgung des Verdampfungstrockners

- Gasturbine zur Reduzierung der Stromaufnahme während der Verwendung eines Verdampfungstrockners
- Kläranlage, die das Kondensat der Dämpfe aus dem Verdampfungstrockner verarbeiten kann.

Tabelle 4.110 zeigt den Energiebedarf und die Produktionswerte der drei Anlagen. Zum Vergleich sind die Werte für eine Anlage, in der die Pressschnitzel nicht getrocknet werden, ebenfalls aufgeführt.

| Prozessstufe   | Einheit   | Dampf<br>trock-<br>nung<br>mit<br>Wirbel<br>schicht<br>trock-<br>nern | Hoch-<br>tempe-<br>ratur-<br>trock-<br>nung | Zwei-<br>stufen-<br>trocknung | Anlage<br>ohne<br>Trocknung |
|--|-----------|---|---|-------------------------------|-----------------------------|
| Verarbeitung der Zuckerrüben   | t/Tag     | 10.000  | 10.000                                      | 10.000                        | 10.000                      |
| Dampfbedarf der<br>Verdampfungsstation   | t/h       | 83,33   | 83,33                                       | 83,33                         | 83,33                       |
| Elektroenergiebedarf für die<br>Trocknung  | MW        | 1,15  | 0,80  | 1,70                          | 0                           |
| Elektroenergiebedarf für die<br>restliche Anlage   | MW        | 10,40   | 10,40                                       | 10,40                         | 10,40                       |
| <b>Gesamtstrombedarf</b>   | <b>MW</b> | <b>11,55</b>  | <b>11,20</b>                                | <b>12,10</b>                  | <b>10,40</b>                |
| Spezifischer Elektroenergiebedarf<br>für die Verarbeitung der<br>Zuckerrüben pro t Rüben | kWh/t     | 27,72   | 26,88                                       | 29,04                         | 24,96                       |
| Wärmeenergie<br>Hochtemperaturtrocknung  | MW        | 0   | 44,70                                       | 37,67                         | 0                           |
| Wärmeenergie für Dampfgenerator  | MW        | 57,12   | 67,13                                       | 67,13                         | 67,13                       |
| Wärmeenergie für Gasturbine  | MW        | 16,60   | 0   | 0                             | 0                           |
| <b>Gesamte thermische Energie</b>  | <b>MW</b> | <b>73,72</b>  | <b>111,83</b>                               | <b>104,80</b>                 | <b>67,13</b>                |
| Elektroenergieabgabe der<br>Dampfturbine   | MW        | 7,92  | 11,66                                       | 11,66                         | 11,66                       |
| Elektroenergieabgabe der<br>Gasturbine   | MW        | 4,00  | 0   | 0                             | 0                           |
| <b>Gesamtelektroenergieabgabe</b>  | <b>MW</b> | <b>11,92</b>  | <b>11,66</b>                                | <b>11,66</b>                  | <b>11,66</b>                |
| Versorgung mit Elektroenergie  | MW        | 0   | 0   | 0,44                          | 0                           |
| Gesamtelektroenergieabgabe   | MW        | 0,37  | 0,46  | 0                             | 1,26                        |

**Tabelle 4.110: Vergleich der Energiebilanzen von drei verschiedenen Verfahren zur Trocknung von Rübenschnitzeln und für eine Anlage ohne Trocknung in Deutschland**

In Bezug auf den Strombedarf liegt die Zweistufentrocknung am höchsten, gefolgt von der Verdampfungstrocknung mit Wirbelschichttrocknern und der Hochtemperaturtrocknung, die am wenigsten elektrische Energie benötigt. Im Vergleich mit dem Strombedarf einer Anlage, in der nicht getrocknet wird, kann man sehen, wie hoch der zusätzliche Bedarf an elektrischer Energie für die einzelnen Techniken ist:

- Hochtemperaturtrocknung: 0,8 MW
- Verdampfungstrocknung mit Wirbelschichttrocknern: 1,15 MW
- Zweistufentrocknung: 1,7 MW.

An thermischer Energie benötigt die Hochtemperaturtrocknung am meisten, gefolgt von der Zweistufentrocknung, während für die Verdampfungstrocknung mit Wirbelschichttrocknern deutlich weniger thermische Energie verbraucht wird. Im Vergleich mit dem Strombedarf einer Anlage, in der nicht getrocknet wird, kann man sehen, wie hoch der zusätzliche Bedarf an thermischer Energie für die einzelnen Techniken ist:

- Hochtemperaturtrocknung: 44,7 MW
- Verdampfungstrocknung mit Wirbelschichttrocknern: 6,59 MW
- Zweistufentrocknung: 37,67 MW.

Für die Abgabe thermischer Energie zur Umwandlung in elektrische Energie gilt Folgendes: Die Hochtemperaturtrocknung hat die höchste Abgabeleistung, gefolgt von der Zweistufentrocknung und schließlich der Verdampfungstrocknung mit Wirbelschichttrocknern.

Bei der Verdampfungstrocknung mit Wirbelschichttrocknern werden nur 6,59 MW für die Trocknung aufgewendet bei einem Gesamtverbrauch an thermischer Energie von 73,72 MW. Durch den Einsatz der Kraft-Wärme-Koppelung ist die Strombilanz der Anlage positiv, da 0,37 MW mehr Strom zur Abgabe erzeugt werden. Obwohl ein erheblicher Teil des Dampfes, der über die Gegendruckturbine bei etwa 27 bar zurückgeleitet wird, nicht vollständig für die Umwandlung in elektrische Energie zur Verfügung steht.

Bei der Hochtemperaturtrocknung werden 44,7 MW für die Trocknung aufgewendet bei einem Gesamtverbrauch an thermischer Energie von 111,83 MW. Der Bedarf an spezifischer thermischer Energie für die Verdampfung von Wasser ist gering, z. B. etwa 1,03 kWh/kg Dampf (3,7 MJ/kg).

Bei der Zweistufentrocknung werden 38% des Wassers im Niedertemperaturtrockner verdampft, aber auf dieser Stufe wird 9,7 Mal so viel Luft benötigt wie bei der darauf folgenden Hochtemperaturtrocknung. Die Niedertemperaturtrocknung hat einen höheren Bedarf an spezifischer Energie. Der Bedarf an thermischer Energie von 34 MW bei der Niedertemperaturtrocknung entspricht etwa 1,9 kWh/kg (7 MJ/kg) für den spezifischen Dampfbedarf, während die 41 MW bei der Hochtemperaturtrocknung einen auf Dampf bezogenen Energieverbrauch von 1,4 kWh/kg (5,2 MJ/kg) ergeben.

Anwendbarkeit

Siehe Abschnitte 4.7.7.1.2, 4.7.7.1.3 und 4.7.7.1.4.

Wirtschaftlichkeit

In Tabelle 4.111 sind die ausgewählten Werte für einen Machbarkeitsvergleich der Beispielanlagen zusammengefasst. Die angegebenen Zahlen sind nur für die oben genannten Bedingungen gültig. Mögliche kleinere Unterschiede bei Einnahmen aus Nebenprodukten bleiben unberücksichtigt.

|   | Einheit              | Verdampfungs-trocknung mit Wirbel-schicht-trocknern | Hoch-tempe-ratur-trock-nung | Zwei-stufen-trock-nung | Anlage ohne Trockner |
|---|----------------------|---|-----------------------------|------------------------|----------------------|
| Gesamtelektroenergiebedarf  | MW                   | 11,55   | 11,20                       | 12,10                  | 10,40                |
| Gesamtbedarf an thermischer Energie   | MW                   | 73,72   | 111,83                      | 104,80                 | 67,13                |
| Gesamtelektroenergieabgabe  | MW                   | 11,48   | 11,66                       | 11,66                  | 11,66                |
| Versorgung mit Elektroenergie   | MW                   | 0,07  | 0                           | 0,44                   | 0                    |
| Gesamtelektroenergieabgabe  | MW                   | 0   | 0,46                        | 0                      | 1,26                 |
| Kosten für Brennstoffe  | EUR/h                | 1.180   | 1.789                       | 1.677                  | 1.074                |
| Kosten für Elektroenergie   | EUR/h                | 0   | 0                           | 18,00                  | 0                    |
| Gesamtelektroenergieabgabe  | EUR/h                | -7,6  | -9,4                        | 0                      | -25,7                |
| <b>Gesamtennergiekosten</b>   | <b>EUR/h</b>         | <b>1.172</b>  | <b>1.780</b>                | <b>1.695</b>           | <b>1.048</b>         |
| Kosten für Brennstoffe  | '000 EUR/Jahr        | 2.548   | 3.865                       | 3.622                  | 2.320                |
| Kosten für Versorgung mit Elektroenergie  | '000 EUR/Jahr        | 0   | 0                           | 38,9                   | 0                    |
| Einnahmen durch Elektroenergieabgabe  | '000 EUR/Jahr        | -16,3   | -20,3                       | 0                      | -55,5                |
| <b>Gesamtennergiekosten</b>   | <b>'000 EUR/Jahr</b> | <b>2.532</b>  | <b>3.845</b>                | <b>3.661</b>           | <b>2.264</b>         |
| Preis für thermische Energie = 16,00 EUR/MWh<br>Preis für Elektroenergie = 40,90 EUR/MWh<br>Dauer der Saison = 2.160 Std./Jahr<br>Preis für abgegebene Elektroenergie = 20,40 EUR/MWh |                      |   |                             |                        |                      |

**Tabelle 4.111: Vergleich der Energiekosten für verschiedene Methoden der Trocknung von Rübenschnittzeln**

Die Standardbedingungen waren ein Druck von 85 bar und eine Temperatur von 525 °C. In einer Reihe von Anlagen wird durch Kraft-Wärme-Koppelung ein geringerer Dampfdruck von z. B. 40-60 bar erzeugt. In diesen Fällen können die oben genannten Einsparungen nicht erwartet werden.

Außerdem kann die Strombilanz einer Anlage mit einem Verdampfungstrockner nur dann ausgewogen gestaltet werden, wenn auch eine Gasturbine betrieben wird. Der nachgeschaltete Dampferzeuger muss so gebaut sein, dass er die Abgase der Gasturbine ausnutzt. Ohne Gasturbine entsteht statt des Überschusses an elektrischer Energie von 0,37 MW ein Energiebedarf von 3,63 MW. Die Kosten für diesen Energieverbrauch belaufen sich auf 2,9 Mio. EUR pro Jahr. Dies würde bedeuten, dass die Einsparungen auf 0,95 Mio. EUR pro Jahr zurückgehen.

Die Dämpfe aus den Trocknern werden kondensiert. Das Kondensat muss behandelt werden. Falls die bestehende Kläranlage nicht die notwendige Kapazität besitzt, um die erzeugte Menge zu behandeln, werden zusätzliche Behandlungskapazitäten benötigt. Allerdings sind die Kosten für die Abwasserbehandlung und damit in Zusammenhang stehende Investitionen nicht in den oben dargelegten Berechnungen enthalten.

Wenn man die obige Tabelle zusammenfasst, dann sind die Energiekosten am geringsten für die Verdampfungstrocknung mit Wirbelschichttrocknern, gefolgt von der Zweistufentrocknung und schließlich der Hochtemperaturtrocknung, die die höchsten Energiekosten verursacht. Andererseits sind die Investitionskosten für die Verdampfungstrocknung mit Wirbelschichttrocknern am höchsten und für die Hochtemperaturtrocknung am niedrigsten.

Es gibt verschiedene Methoden zur Bewertung der Aufwendungen; eine davon ist die Berechnung des Net Present Value (NPV). NPV ist der Wert einer Investition, berechnet als Summe der abdiskontierten zukünftigen Zahlungen abzüglich der Kosten für die laufende Investition:

$$\text{NPV} = -(\text{Kosten der Investition}) + \sum_{i=1}^n \left( \frac{\text{income}_i}{(1+r)^i} \right)$$

mit

NPV = Net Present Value

Erträge = Nettoerträge; können nach Berücksichtigung aller Kosten auch negativ sein

r = Abzinsungssatz (Zinsen in %/100)

i = Jahr

n = Betriebszeit einer Anlage in Jahren

Tabelle 4.112 zeigt einen Vergleich der Ausgaben, ausgedrückt als NPV, für die drei Techniken.

|                                      |          | Verdampfungstrocknung mit Wirbelschichttrocknern | Hochtemperaturtrocknung | Zweistufentrocknung |
|--------------------------------------|----------|--|-------------------------|---------------------|
| <b>Investitionskosten</b>            | Mio. EUR |  |                         |                     |
| Trockner                             |          | 16   | 10                      | 13                  |
| Gasturbine                           |          | 4  |                         |                     |
| <b>Summe der Investitionskosten</b>  |          | 20   | 10                      | 13                  |
| <b>Betriebskosten</b>                | Mio. EUR |  |                         |                     |
| Elektroenergie                       |          | -2,5   | -3,8                    | -3,7                |
| Sonstige                             |          | -0,6   | -0,4                    | -0,5                |
| <b>Summe der Betriebskosten</b>      |          | -3,1   | -4,2                    | -4,2                |
| Betriebszeit einer Anlage = 10 Jahre |          |  |                         |                     |
| Abzinsungssatz, r = 0,08             |          |  |                         |                     |
| <b>Net Present Value (NPV)</b>       | Mio. EUR | <b>-40,9</b>                                     | <b>-38,4</b>            | <b>-40,7</b>        |

Tabelle 4.112: Vergleich der Aufwendungen, ausgedrückt als NPV

Die Verdampfungstrocknung mit Wirbelschichttrocknern und die Zweistufentrocknung haben praktisch den gleichen Net Present Value (NPV), während die Hochtemperaturtrocknung um etwa 6% preiswerter ist. Wird

die Berechnung jedoch auf Grundlage einer längeren betrieblichen Lebensdauer, d. h. 18 Jahre, für Trockner und Gasturbine erstellt, dann ist der NPV für die Verdampfungstrocknung mit Wirbelschichttrockner der niedrigste, z. B. niedrigste Kosten.

### Referenzliteratur

[65, Germany, 2002]

#### 4.7.7.2 Verringerung des Erdanteils bei den Zuckerrüben

##### Beschreibung

Mit den angelieferten Zuckerrüben gelangen große Mengen an Erde, Kies und Steinen mit in die Zuckerfabriken. Beim Umgang mit diesem unerwünschten Material wird in der Anlage eine große Menge an Ressourcen, z. B. Energie und Wasser, verbraucht. Durch ein Projekt „Saubere Rüben“ mit einer Kombination aus technischen und wirtschaftlichen Maßnahmen sowie entsprechenden Züchtungen kann die in der Anlage angelieferte Erdmenge verringert werden.

##### Erreichbare Umweltvorteile

Geringerer Wasser- und Energieverbrauch.

##### Betriebsdaten

Eine schwedische Beispielanlage konzentriert sich seit den frühen 80er Jahren auf die Verringerung des Erdanteils. Ein Projekt „Saubere Rüben“ hat zu einer Verringerung des Erdanteils um 150.000 t geführt. Wegen der größeren Rübenanbaufläche ist die aus Dänemark gemeldete Zahl sogar noch höher. Die Werte liegen nun 50% unter den Werten, die noch vor 10 Jahren üblich waren.

Außerdem wird in Schweden und Dänemark mit einem besonderen Bonussystem darauf hingewirkt, dass die Ernte bei gutem Wetter durchgeführt und die Erntegeräte optimal eingesetzt werden. Testläufe in einer Beispielanlage lassen den Schluss zu, dass es beim richtigen Einsatz neuer Erntemaschinen unter fast allen Wetterbedingungen möglich ist, einen Erdanteil von 5% (Reinheit 95%) zu erreichen. Abbildung 4.73 zeigt die Verringerung des Erdanteils in Schweden.

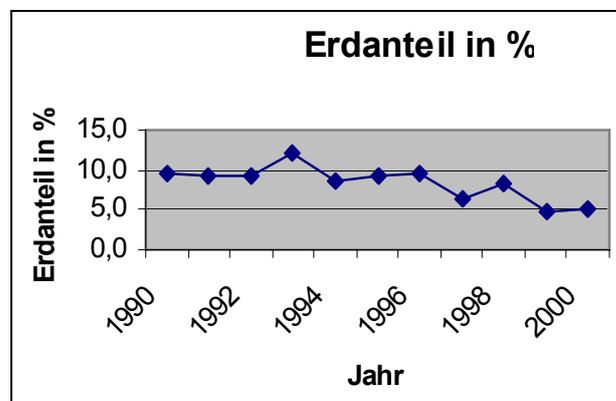


Abbildung 4.73: Verringerung des Erdanteils in Schweden

Parallel dazu arbeiten diese Anlagen auch an einer Verbesserung der Form der Rüben, um sicherzustellen, dass weniger Erdreich an den Knollen haften bleibt. Die Züchtung mit Hilfe traditioneller Züchtungsmethoden konzentriert sich auf die Furche im Wurzelbereich der Rübe, die beim Waschen der Rübe das größte Problem darstellt.

##### Anwendbarkeit

In der Zuckerherstellung anwendbar.

##### Wirtschaftlichkeit

Geringerer Energie- und Wasserverbrauch.

##### Anlass für die Umsetzung

Geringerer Energie- und Wasserverbrauch.

Beispielanlagen

Zuckerhersteller in Schweden und Dänemark.

Referenzliteratur

[1, CIAA, 2002]

**4.7.7.3 Wiederverwendung des Rübenwaschwassers bzw. -abwassers**Beschreibung

Ein großer Teil des bei der Zuckerrübenverarbeitung entstehenden Abwassers ist das Schwemmwasser, mit dem die Rüben in den ersten Stufen der Verarbeitung transportiert werden. Das Schwemmwasser kann etwa 20 Mal verwendet werden, bevor es abgegeben wird. Letztliches Ziel für den Verbrauch von Wasser zum Transport mag die Null-Entnahme aus externen Wasserquellen sein.

An vielen Standorten wird das Transportwasser in umfangreichen Kreisläufen, gewöhnlich erst nach einer Zwischenreinigung in Absetzteichen, wiederverwendet. Da sich im Schwemmwasser organische saure Verbindungen bilden, wurde bisher der pH-Wert korrigiert, und zwar normalerweise mit Kalk. Es wurde jedoch festgestellt, dass bei biologischer Klärung des Abwassers der pH-Wert nicht mehr korrigiert werden muss. Durch schonenden Umgang mit den Rüben während des Transports zur Minimierung von Beschädigungen werden Auswaschungen von Zucker in das Transportwasser und folglich auch der CSB-Gehalt und das erforderliche Ausmaß der Abwasserbehandlung vor der Wiederverwendung reduziert.

Es wird berichtet, dass es in den meisten Fällen möglich ist, sofern ausreichend Lagerkapazität besteht, das Wasser aus der Vorjahressaison aufzubewahren und die neue Saison damit zu beginnen. Dadurch erübrigt sich die Notwendigkeit, Oberflächenwasser oder Grundwasser zu entnehmen. Überschüssiges Wasser, das nicht für die nächste Saison eingesetzt werden kann, wird dem Oberflächengewässer wieder zugeführt. Manche Anlagen bringen das Gemisch aus Erde und Wasser auch auf landwirtschaftlichen Nutzflächen aus (siehe Abschnitt 4.1.6).

Kondensat aus den Verdampfungs- und Kristallisationsstufen wird teilweise als Prozesswasser in verschiedenen Stufen eingesetzt, auch für das Waschen der Rüben. Kondensat kann auch als Quelle von Wasser geringer Qualität angesehen werden. Beispielsweise wird berichtet, dass Zuckerraffinerien sehr wassereffizient arbeiten können, sodass das gesamte Frischwasser im Prozess verwendet und das Kondensat vollständig wiederverwertet wird. Zuckerrüben bestehen zu 75 % aus Wasser, und das Extraktionsverfahren zielt erklärtermaßen darauf ab, eine große Menge dieses Wassers freizusetzen. Etwa die Hälfte dieses Wassers geht beim Verdampfen verloren oder wird in die verschiedenen Produktströme eingebracht.

Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs.

Betriebsdaten

In modernen Zuckerfabriken beträgt der Frischwasserverbrauch zurzeit 0,25-0,4 m<sup>3</sup>/t verarbeiteter Rüben. In neuen Anlagen kann der Wasserverbrauch auf 0,1 m<sup>3</sup>/t verarbeiteter Rüben gesenkt werden.

Anwendbarkeit

Anwendbar in Anlagen, die Zucker aus Zuckerrüben herstellen.

Anlass für die Umsetzung

Verringerung des Wasserverbrauchs.

Beispielanlagen

Wird in Anlagen genutzt, die Zucker aus Zuckerrüben herstellen.

Referenzliteratur

[1, CIAA, 2002, 13, Environment Agency of England and Wales, 2000, 61, CEFS, 2001, 134, AWARENET, 2002]

### 4.7.8 Kaffee

#### 4.7.8.1 Abwärmenutzung bei der Herstellung von Instantkaffee

##### Beschreibung

Die Herstellung von Instantkaffee ist ausgesprochen energieaufwendig (siehe Abschnitt 2.2.13.2 zur Beschreibung der Herstellung von Instantkaffee). Abwärme, z. B. aus der Extraktionsstufe oder von Luftkompressoren, kann während der Produktion weiter genutzt werden, z. B. für die Extraktion oder als Heizquelle z. B. für Büros und Lagerräume. Ein Standardverfahren zur Nutzung von Abwärme ist auch die Rezirkulation eines Teils der Abluft innerhalb der Anlage, z. B. in der Sprühtrocknung unter Verwendung von Gegenstromwärmetauschern und innerhalb der Röstung.

##### Erreichbare Umweltvorteile

Geringerer Energieverbrauch, da die Wärme wiederverwendet wird.

##### Betriebsdaten

In einer Beispielanlage in Deutschland wird der heiße, flüssige Kaffeeextrakt, der bei der Extraktion entsteht, durch Wärmetauscher gepumpt, die dem Kaffee Wärme entziehen und gleichzeitig das für die Extraktion erforderliche Prozesswasser erhitzen. Zusätzlich werden mit der Abwärme aus der Produktion die Büros und Aufenthaltsräume des Betriebs geheizt. Außerdem wird die Abwärme der Luftkompressoren für das Heizen der Lagerhallen genutzt.

##### Anwendbarkeit

Die Wiederverwendung minderwertiger Wärme ist in der Nahrungsmittelproduktion weit verbreitet.

##### Wirtschaftlichkeit

Geringere Energiekosten.

##### Beispielanlagen

Eine Beispielanlage in Deutschland.

##### Referenzliteratur

[65, Germany, 2002]

#### 4.7.8.2 Vermeidung von Luftemissionen aus der Agglomerationsstufe bei der Herstellung von Instantkaffee

Die Herstellung von Instantkaffee ist in Abschnitt 2.2.13.2 beschrieben.

##### Beschreibung

Bei der Herstellung von Instantkaffee wird nach dem Trocknen ein Teil des Endproduktes zur Agglomeration transportiert. Bei der Agglomeration entsteht ein sehr hoher Staubanteil, der größtenteils rezirkuliert wird. Nachgeschaltete Faserfiltersysteme (siehe Abschnitt 4.4.3.7) mit integrierten Staubabscheidern verhindern, dass Staubpartikel in die Abluft gelangen.

##### Erreichbare Umweltvorteile

Geringere Staubemissionen.

##### Betriebsdaten

Faserfilter sind sehr effizient. Der angegebene Reststaubgehalt in der Abluft liegt im Bereich von  $<1\text{mg/Nm}^3$ .

##### Beispielanlagen

Eine Beispielanlage in Deutschland.

##### Referenzliteratur

[65, Germany, 2002]

#### 4.7.8.3 Nutzung von Biofiltern in der Kaffeeverarbeitung

Weitere Informationen zu dieser Technik siehe Abschnitt 4.4.3.10.1.

Beschreibung

In einer Beispielanlage werden Biofilter eingesetzt, um Geruchsemissionen aus der Kaffeeverarbeitung zu verhindern. Die wichtigsten Kontaminanten in der Abluft aus der Röstung von Kaffee sind CO<sub>2</sub>, Staub und Formaldehyd. Die Emissionen hängen von der Zusammensetzung des Rohkaffees, vom Röstgrad und vom Restfeuchtegehalt ab. Die wichtigsten betrieblichen Abläufe, bei denen Emissionen in die Luft erwartet werden, sind das Vorheizen der Röstkammer, das Rösten, das Vorkühlen des Produktes im Sprühwassernebel, das Trocknen des Produktes, das Entleeren der Röstkammer und das Kühlen. Während des Kühlens mit Luft fallen erhebliche Mengen an Luft an, die einer nachfolgenden Behandlung bedürfen.

In der Anlage sind Mahl- und Vakuumkammern mit Zwangsbelüftung in Betrieb. Die CO<sub>2</sub>-Emissionen und die restlichen, nicht verbrannten Kohlenwasserstoffe können leicht in einem geschlossenen System aufgefangen werden. In der Beispielanlage werden mit einem Biofilter in Modulbauweise 8.600 m<sup>3</sup> Luft pro Stunde behandelt. Dieser Filter besteht aus einem Gegenstrombefeuchter mit Packmaterial aus Polyethylen. Das Filtermaterial ist kompostierter Rindenmulch. Die Filtermodule bestehen aus Edelstahlzylindern mit einem Gesamtvolumen von 198 m<sup>3</sup>. Zur Ausstattung gehören auch ein Radiallüfter mit einer Leistung von 15 kW und ein Steuerpult. Pro m<sup>3</sup> Filtermaterial können maximal 43,5 m<sup>3</sup> Abluft behandelt werden. Bei dieser Beladung werden keine Geruchsemissionen festgestellt.

Der Geruch von Kaffee ist noch bei so geringen Werten wie 3,5 GE/m<sup>3</sup> deutlich wahrnehmbar.

Erreichbare Umweltvorteile

Geruchsemissionen werden vollständig eliminiert.

Medienübergreifende Effekte

Entsorgung des Filtermaterials. Zur Reduzierung der organischen Belastung wird das benutzte Material kompostiert und dann zur Ausbringung auf landwirtschaftlichen Nutzflächen weitergegeben. Das kondensierte Wasser wird wiederverwendet; andernfalls müsste es behandelt werden.

Betriebsdaten

Pro m<sup>3</sup> Filtermaterial können maximal 43,5 m<sup>3</sup> Abluft behandelt werden. Bei dieser Beladung werden nach der Behandlung keine Geruchsemissionen festgestellt. Es gibt keine Daten über andere Emissionsgrade.

Wirtschaftlichkeit

Das gesamte System hat 63.480 EUR gekostet (Deutschland, 2001).

Referenzliteratur

[65, Germany, 2002, 170, InfoMil, 2001]

**4.7.8.4 Kaffeeröstung**

Rohkaffee kann kontinuierlich oder chargenweise geröstet werden. Bei der Röstung fällt kein Abwasser an. Die Kaffeehäutchen, die beim Rösten anfallen und je nach Art des Kaffees bis zu 2% ausmachen können, werden entweder als Heizmaterial verwendet oder kompostiert.

In einem **Chargenröster** werden die Kaffeebohnen verwirbelt und mit tangential eintretender Heißluft auf Rösttemperatur gebracht. Das Röstverfahren wird dadurch beendet, dass Wasser in die Röstkammer geleitet wird. Dann werden die Kaffeebohnen in den Kühler umgefüllt. Die Kaffeehäutchen, die während des Röstvorgangs abblättern, werden vom Röstzyklon zurückgehalten. Die Luft wird im Umluftbetrieb durch einen Heizofen geleitet. Überschüssige Luft wird behandelt, bevor sie ins Freie geleitet wird. Der Röstvorgang beträgt 1 – 5,5 Minuten. Die Röstkammer wird erst nach dem Abschluss des Röstvorgangs, oder alternativ nach ihrer Entleerung, erneut mit Rohkaffee beschickt. Die für die abrupte Unterbrechung des Röstvorgangs nötige Wassermenge beläuft sich auf 10-15% des Gewichts des Rohkaffees.

Chargenröster bieten breitgefächerte Röstmöglichkeiten, die die Verarbeitung der unterschiedlichsten Rohkaffeearten mit unterschiedlichsten Röstergebnissen zulassen. In einer Anlage in Deutschland kommt zum Beispiel ein Röster mit einer Leistung von bis zu 4.000 kg/h zum Einsatz. Dieser Röster eignet sich insbesondere für Röstereien, die eine große Vielfalt an Produkten anbieten, hohe Erwartungen an die Qualität erfüllen müssen und große Mengen produzieren. In Abbildung 4.74 ist der in Deutschland betriebene Chargenröster schematisch dargestellt.

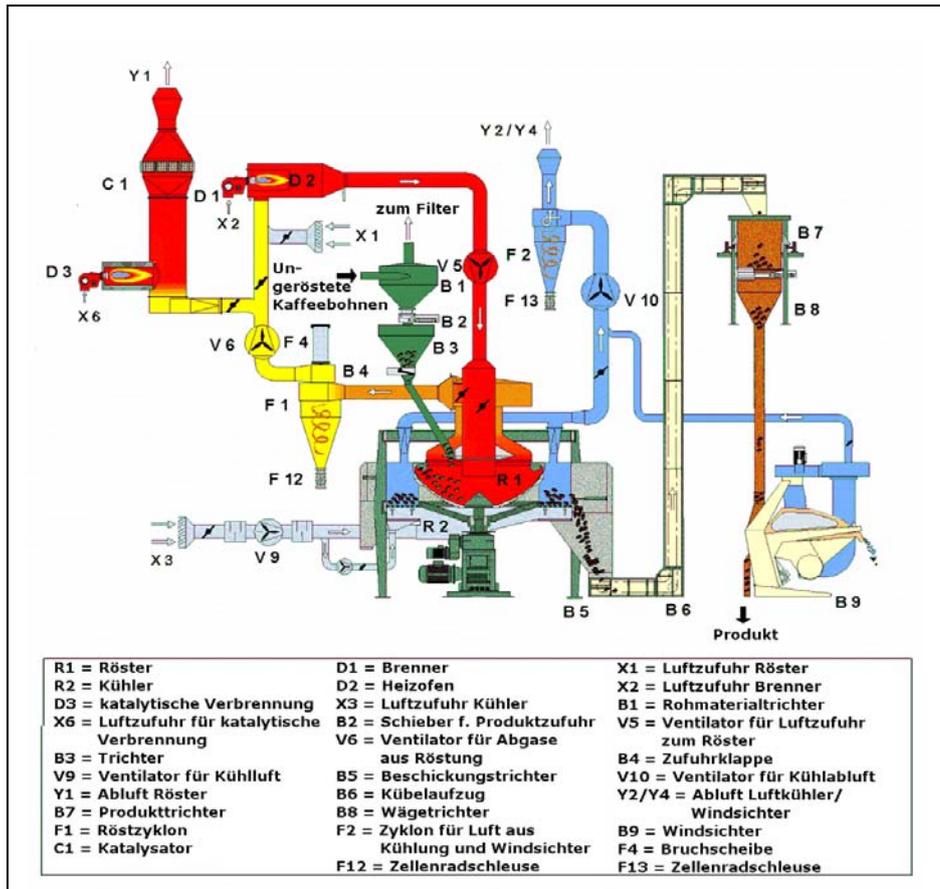


Abbildung 4.74: In einem deutschen Kaffeeunternehmen betriebener Chargenröster [65, Germany, 2002]

Bei einem **kontinuierlichen Röster** wird Rohkaffee ohne Unterbrechung zugeführt und beim Durchlauf durch den Röster geröstet und gekühlt. Die Kaffeebohnen durchlaufen in kleinen Mengen eine Rösttrommel, die aus kleinen Abteilungen besteht. Die Kaffeebohnen werden durch die Bewegung der Trommel und die eingeleitete Heißluft durchmischt. Da der Röstvorgang in Kleinstchargen stattfindet, ist es nicht möglich, das Produkt zu ersetzen, ohne den Röstvorgang zu unterbrechen. Staub und Häutchen werden in einem Zyklon entfernt. Kontinuierliche Röster sind insbesondere dann von Vorteil, wenn nur wenige verschiedene Kaffeesorten geröstet werden sollen und das Rösten im Schichtbetrieb stattfindet.

In Deutschland eingesetzte Röster können den Angaben zufolge bis zu 4.000 kg/h verarbeiten, und die Röstzeiten liegen zwischen einer und acht Minuten. In Abbildung 4.75 ist ein in Deutschland betriebener kontinuierlicher Kaffeeröster schematisch dargestellt.

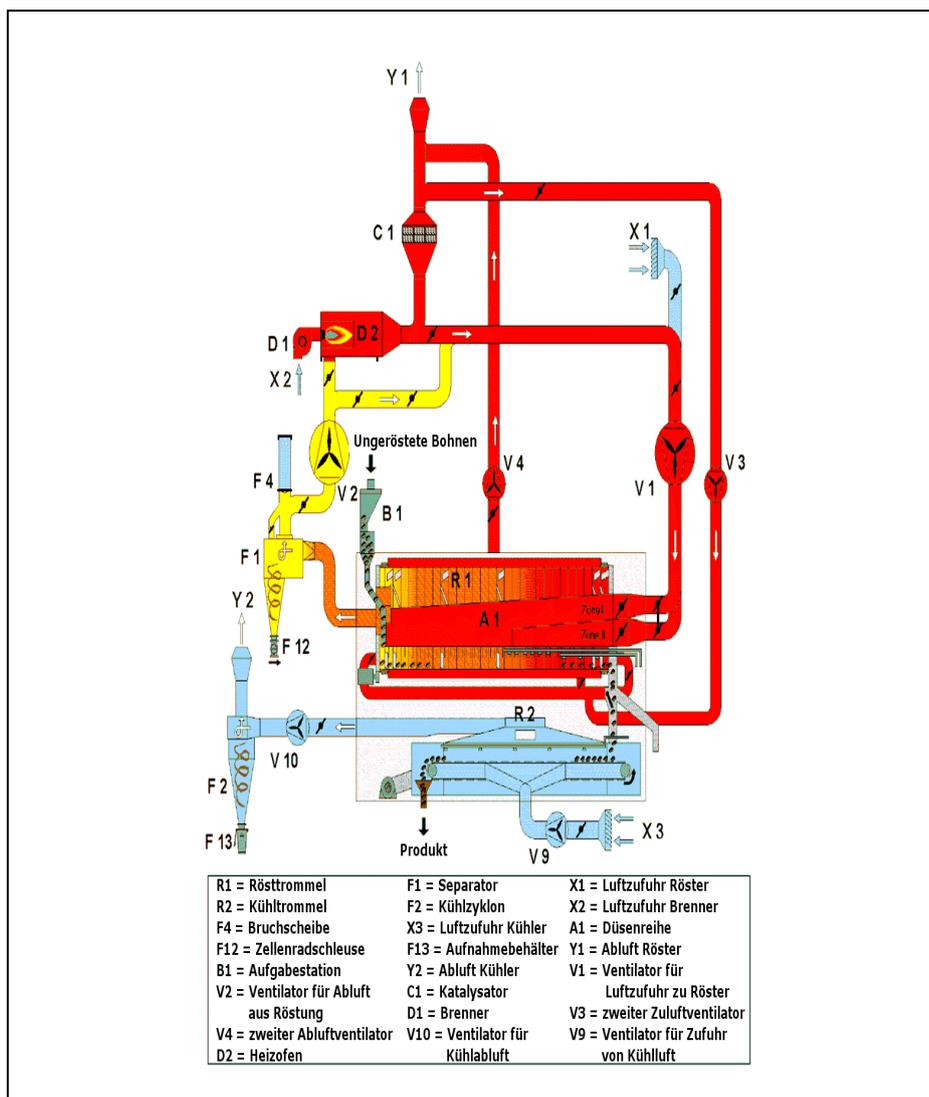


Abbildung 4.75: Kontinuierliche Kaffeeröstung in einem deutschen Unternehmen [65, Germany, 2002]

#### 4.7.8.4.1 Kaffeeröstung im Umluftbetrieb

##### Beschreibung

Bezüglich der Röstluftzufuhr ist zu unterscheiden zwischen Röstern ohne Rezirkulation und Umluftröstern. Umluftröster verbrauchen weniger Energie und erzeugen geringere Abgasmengen, die dann behandelt werden müssen.

##### Erreichbare Umweltvorteile

Umluftröster verbrauchen weniger Energie und erzeugen geringere Mengen an zu behandelndem Abgas als Röster, die ohne Umluft arbeiten.

##### Betriebsdaten

Umluftröster verbrauchen bis zu 25% weniger Energie als Röster, die ohne Umluft arbeiten. Tabelle 4.113 zeigt die Staubbelastung aus Röstern mit und ohne Rezirkulation.

|                    | Staubgehalt hinter dem Zyklon (mg/Nm <sup>3</sup> ) |
|--------------------|---|
| Umluftröster       | 20 – 150  |
| Röster ohne Umluft | 200 – 400   |

Tabelle 4.113: Staubgehalt hinter dem Zyklon

### Anwendbarkeit

In allen Kaffeeröstanlagen anwendbar.

### Wirtschaftlichkeit

Geringere Kosten für Energie und Abgasbehandlung.

### Beispielanlagen

Überwiegend im Kaffeesektor in Deutschland eingesetzt im Vergleich zu Röstanlagen ohne Umluft.

### Referenzliteratur

[65, Germany, 2002]

#### **4.7.8.4.2 Wassernebelkühlung von Röstkaffee**

### Beschreibung

Zum Abkühlen des Produktes wird ein feiner Wassernebel in die Kammer geleitet. Wenn die Wasser-Luft-Aerosole mit den heißen, gerösteten Kaffeebohnen in Kontakt kommen, verdunsten die Wassertröpfchen.

### Erreichbare Umweltvorteile

Weniger Luftverschmutzung und geringerer Energieverbrauch als bei Luftkühlung.

### Betriebsdaten

Bei der Kühlung mittels Wassernebel werden erheblich geringere Mengen an Luft benötigt als vergleichsweise bei einer reinen Luftkühlung; folglich muss auch weniger Abluft behandelt werden und die Geruchsemissionen verringern sich. Tabelle 4.114 zeigt die Zusammensetzung des Abgases aus der reinen Luftkühlung vor der Abluftbehandlung (d. h. höhere Werte als bei der Kühlung mit Wassernebel). Im Vergleich zur Wassernebelkühlung wird bei der Luftkühlung weniger Energie verbraucht (siehe Tabelle 4.115) und es fällt kein Abwasser an.

|  |         |
|--|---------|
| <b>Abgastemperatur (°C)</b>                | 40      |
| <b>Abgasvolumen (m<sup>3</sup>/kg)*</b>    | 2 – 7,5 |
| <b>TOC-Emissionen (mg/Nm<sup>3</sup>)</b>  | 20      |
| <b>Staubemissionen (mg/Nm<sup>3</sup>)</b> | 75      |
| * 10 Vol% des Röstgasvolumens              |         |

**Tabelle 4.114: Zusammensetzung des Abgases aus der Luftkühlung vor Behandlung**

Die Emissionen, die beim Kühlen mit Wassernebel entstehen, werden über das Abluftbehandlungssystem des Rösters entfernt.

### Anwendbarkeit

Der abgekühlte Kaffee verlässt den Röster mit einer Temperatur von etwa 60 °C, was für gemahlene Kaffee zu hoch und nicht optimal ist. Bei einigen Kaffeesorten kann eine Endtemperatur von 60 °C zu einem akzeptablen Geschmack führen, aber bei den meisten Kaffeesorten ist dies nicht der Fall. Über 90% des in Europa verwendeten Röstkaffees ist gemahlener Kaffee. Daher kann dieses Kühlsystem nur unter bestimmten Bedingungen benutzt werden. Das Verfahren wird in erster Linie in dicht bebauten Wohngebieten eingesetzt.

### Wirtschaftlichkeit

Geringere Kosten für Energie und Abgasbehandlung als bei Luftkühlung.

### Beispielanlagen

Wird in deutschen Kaffeeunternehmen eingesetzt.

### Referenzliteratur

[65, Germany, 2002, 186, CIAA-EUCA, 2003]

#### 4.7.8.4.3 Kaffeeröstung mit nachfolgender katalytischer Oxidation der Abgase

##### Beschreibung

Eine als Beispielanlage fungierende neu errichtete Kaffee Großrösterei in Deutschland, in diesem Abschnitt **Werk A** genannt, setzt Chargenröster und kontinuierliche Röster mit Umluftbetrieb (siehe Abschnitt 4.7.8.4.1) ein und hat eine Röstkapazität von etwa 12.000 t/Jahr im Zwei-Schichtbetrieb. Röstung, Lagerung und Transport des gerösteten oder gemahlene Kaffees finden unter Schutzgas statt, d. h. in einer sauerstoffarmen Umgebung. Die sauerstoffarme Umgebung wird erzeugt, indem der Luft für den pneumatischen Transport der Behälter mit gemahlene und geröstetem Kaffee pro kg Röstkaffee etwa 2 l Kohlenmonoxid aus dem Mahlvorgang zugesetzt werden. Leitungen und Behälter müssen gasdicht sein, damit das eingesetzte Gas im System verbleibt. Das Abgas wird einer katalytischen Verbrennung unterworfen.

**Werk B** ist eine andere als Beispiel dienende Kaffee Großrösterei, in der ausschließlich 500-g-Vakuumverpackungen hergestellt werden. Die Jahreskapazität beträgt 44.500 t Röstkaffee bei einer Betriebszeit von 3.900 Stunden; durchschnittlich werden in zwei Schichten pro Tag 140 t Röstkaffee hergestellt. Es kommen fünf Röstlinien mit einer Gesamtkapazität von 13.640 kg/h zum Einsatz. Die Röstanlagen sind Chargenröster mit Umluft (siehe Abschnitt 4.7.8.4.1) mit einer Kapazität von etwa 2.200 kg/h und Röster mit Wasserkühlung (siehe Abschnitt 4.7.8.4.2) mit einer Kapazität von etwa 3.080 kg/h. Die Abgase werden mittels katalytischer Verbrennung behandelt, wodurch Geruchsemissionen weitgehend verhindert werden. Mit dem Kohlendioxid aus den Kaffeemahlanlagen wird der gemahlene Kaffee vor Sauerstoffeinwirkung geschützt, bis er vakuumverpackt ist.

##### Erreichbare Umweltvorteile

Siehe Abschnitt 4.4.3.11.3.

##### Medienübergreifende Effekte

Siehe Abschnitt 4.4.3.11.3.

##### Betriebsdaten

Tabelle 4.115 zeigt einen Vergleich zwischen den Verbrauchs- und Emissionswerten der verschiedenen Kaffeeröstverfahren.

| Verbrauchs- und Emissionswerte   | Einheit <sup>1</sup> | Emissionswerte eines Rösters <sup>2</sup> vor Abgasbehandlung | Werk A Chargenröster mit Umluft und Luftkühlung | Werk A Kontinuierlicher Röster mit Umluft und Luftkühlung | Werk B Chargenröster mit Umluft und Wassernebelkühlung (Werte von 2001) |
|--|----------------------|---|---|---|---|
| Gesamt-Wasserverbrauch   | l/t                  |   |   |   | 169,2   |
| Wasserverbrauch beim Rösten  | l/t                  |   |   |   | 130   |
| Wasserverbrauch Kühlsystem   | l/t                  |   |   |   | 200   |
| Eingesetztes Heizöl  | l/t                  |   |   |   | 42,04   |
| Gesamt-Energieverbrauch  | kWh/t                |   | 490   | 470   | 115,21  |
| Energieverbrauch beim Rösten   | kWh/t                |   |   |   | 49,6  |
| Energieverbrauch beim Verpacken  | kWh/t                |   |   |   | 19,6  |
| Energieverbrauch beim Mahlen   | kWh/t                |   |   |   | 19,6  |
| Lärmemissionen des Röstlers  | dB(A)                |   | 75  | 75  | 75  |
| Lärmemissionen der Ventilatoren  | dB(A)                |   | 96  | 96  |   |
| Zu kompostierende Abfallmenge nach dem Pressen in Pellets, z. B. Kaffeehütchen   | kg/t                 | 5 – 10*   |   |   | 2,5   |
| Die unten stehenden Luftemissionswerte wurden nach der katalytischen Verbrennung gemessen, ausgenommen <sup>2</sup>                    |                      |   |   |   |   |
| Staubemissionen  | mg/Nm <sup>3</sup>   |   | <20   | <50   |   |
| Staubbelastung   | kg/h                 |   | 0,1   | 0,018 – 0,275   |   |
| TOC-Emissionen (Konzentration)   | mg/Nm <sup>3</sup>   | 10.000  | <50   | <50   | 3,8 – 29,2  |
|  | kg/t                 |   |   |   | 0,00963   |
| TOC-Emissionen (Belastung)   | kg/h                 |   | 0,25  | 0,018 – 0,275   |   |
| Geruchsemissionen <sup>3</sup><br>Der Geruch von Kaffee ist noch bei so geringen Werten wie 3,5 GE/m <sup>3</sup> deutlich wahrnehmbar | GE/Nm <sup>3</sup>   | 150.000   |   |   | 577 – 1.138   |
|  | GE/Nm <sup>3</sup>   | 300.000   |   |   | 1.155 – 2.276   |
| Kohlendioxid (CO <sub>2</sub> )  | Vol-%                | 1 – 3   |   |   |   |
| Kohlenmonoxid (CO)   | mg/Nm <sup>3</sup>   | 500 – 3.000   |   |   |   |
| <sup>1</sup> pro Einheit Rohkaffee   |                      |   |   |   |   |
| <sup>2</sup> Art der Röstung nicht angegeben, z. B. Chargenröstung oder kontinuierliche Röstung  |                      |   |   |   |   |
| <sup>3</sup> gemäß VDI-Richtlinie 3881 – Blatt 1-4   |                      |   |   |   |   |
| *25 l/kg, Teilchengröße >100 µg  |                      |   |   |   |   |

Tabelle 4.115: Vergleich der Verbrauchs- und Emissionswerte der verschiedenen Kaffeeröstverfahren

Wirtschaftlichkeit

In **Werk B** betragen die Investitionen zur Verringerung der Emissionen während des Röstvorgangs etwa 5-10% der Gesamtinvestition für die Röst- und Verpackungslinie ohne Gebäudeteile.

Referenzliteratur

[65, Germany, 2002, 170, InfoMil, 2001]

#### 4.7.8.4.4 Nutzung von Biofiltern in der Kaffeeverarbeitung<sup>36</sup>

Weitere Informationen zu dieser Technik siehe Abschnitt 4.4.3.10.1.

##### Beschreibung

In einer Beispielanlage werden Biofilter eingesetzt, um Geruchsemissionen aus der Kaffeeverarbeitung zu verhindern. Die wichtigsten Kontaminanten in der Abluft aus der Röstung von Kaffee sind CO<sub>2</sub>, Staub und Formaldehyd. Die Emissionen hängen von der Zusammensetzung des Rohkaffees, vom Röstgrad und vom Restfeuchtegehalt ab. Die wichtigsten betrieblichen Abläufe, bei denen Emissionen in die Luft erwartet werden, sind das Vorheizen der Röstkammer, das Rösten, das Vorkühlen des Produktes im Sprühwassernebel, das Trocknen des Produktes, das Entleeren der Röstkammer und das Kühlen. Während des Kühlens mit Luft fallen erhebliche Mengen an Luft an, die einer nachfolgenden Behandlung bedürfen.

In der Anlage sind Mahl- und Vakuumkammern mit Zwangsbelüftung in Betrieb. Die CO<sub>2</sub>-Emissionen und die restlichen, nicht verbrannten Kohlenwasserstoffe können leicht in einem geschlossenen System aufgefangen werden. In der Beispielanlage werden mit einem Biofilter in Modulbauweise 8.600 m<sup>3</sup> Luft pro Stunde behandelt. Dieser Filter besteht aus einem Gegenstrombefeuchter mit Packmaterial aus Polyethylen. Das Filtermaterial ist kompostierter Rindenmulch. Die Filtermodule bestehen aus Edelstahlzylindern mit einem Gesamtvolumen von 198 m<sup>3</sup>. Zur Ausstattung gehören auch ein Radiallüfter mit einer Leistung von 15 kW und ein Steuerpult. Pro m<sup>3</sup> Filtermaterial können maximal 43,5 m<sup>3</sup> Abluft behandelt werden. Bei dieser Beladung werden keine Geruchsemissionen festgestellt.

Der Geruch von Kaffee ist noch bei so geringen Werten wie 3,5 GE/m<sup>3</sup> deutlich wahrnehmbar.

##### Erreichbare Umweltvorteile

Geruchsemissionen werden vollständig eliminiert.

##### Medienübergreifende Effekte

Entsorgung des Filtermaterials. Zur Reduzierung der organischen Belastung wird das benutzte Material kompostiert und dann zur Ausbringung auf landwirtschaftlichen Nutzflächen weitergegeben. Das kondensierte Wasser wird wiederverwendet; andernfalls müsste es behandelt werden.

##### Betriebsdaten

Pro m<sup>3</sup> Filtermaterial können maximal 43,5 m<sup>3</sup> Abluft behandelt werden. Bei dieser Beladung werden nach der Behandlung keine Geruchsemissionen festgestellt. Es gibt keine Daten über andere Emissionsgrade.

##### Wirtschaftlichkeit

Das gesamte System hat 63480 EUR gekostet (Deutschland, 2001).

##### Referenzliteratur

[65, Germany, 2002, 170, InfoMil, 2001]

### 4.7.9 Getränke

#### 4.7.9.1 Trennung der anfallenden Stoffe zur Optimierung der Verwendung, Wiederverwendung, Wiederverwertung und Entsorgung (und Minimierung des Wasserverbrauchs und der Abwasserkontamination)

Diese Technik wird in Abschnitt 4.1.7.6 beschrieben.

##### Dokumentierte Beispiele für die Anwendung der Technik

Es gibt wahrscheinlich noch zahlreiche andere Möglichkeiten, wie diese Technik innerhalb des Sektors eingesetzt werden kann.

- eine Klärung erfordert die Verwendung von Schönungsmitteln. Es wird berichtet, dass der Niederschlag aus der Klärung durch Zentrifugation oder Filtration getrennt wird
- während der alkoholischen Gärung wird der Bodensatz (Abstich) alle drei bis vier Monate vom Wein getrennt und gesammelt, anstatt ihn in die Kläranlage zu spülen

<sup>36</sup> Anm. d. Übers. u. d. UBA-Bearb.: Punkt ist bereits unter 4.7.8.3 abgehandelt!

- vor der Abfüllung in Flaschen wird der Wein filtriert, um restliche Feststoffe und unlösliche Trübungsbestandteile zu entfernen
- Abwasser mit einem hohen Anteil an Zucker/fermentierbaren Substanzen kann in anderen Industriezweigen wiederverwendet werden, z. B. bei der Hefeproduktion
- Rückführung der alkoholischen Flüssigkeiten in den Prozess oder Rückgewinnung als Tierfutter (siehe Abschnitt 4.1.7.7) oder andere Wiederverwendung
- Sammeln der Reste aus den zurückkommenden Containern, anstatt diese Reste in den Abguss zu spülen.

### Anwendbarkeit

In allen Anlagen der Getränkeherstellung anwendbar.

### Referenzliteratur

[134, AWARENET, 2002]

### **4.7.9.2 Trockenreinigung**

Diese Technik wird in Abschnitt 4.3.1 beschrieben.

### Dokumentierte Beispiele für die Anwendung der Technik

Es gibt wahrscheinlich noch zahlreiche andere Möglichkeiten, wie diese Technik innerhalb des Sektors eingesetzt werden kann.

- die Reste aus der Weinherstellung, z. B. Traubenstengel, Trester und Bodensatz werden getrennt gesammelt, bevor die Geräte mit Wasser gereinigt werden
- Abscheider über Bodenabläufen halten Reste, z. B. Kerne und Fruchthaut, vom Abwassersystem fern

### Anwendbarkeit

In allen Anlagen der Getränkeherstellung anwendbar.

### Referenzliteratur

[134, AWARENET, 2002]

### **4.7.9.3 Rückgewinnung der Hefe nach der Fermentation**

### Beschreibung

Nach der Fermentation wird die Brauereihefe abgetrennt und in Lagertanks aufbewahrt, um als Tierfutter (siehe Abschnitt 4.1.7.7), wieder im Fermentationsprozess oder für pharmazeutische Zwecke verwendet oder in anaeroben Kläranlagen zur Produktion von Biogas eingesetzt oder als Abfall entsorgt zu werden.

### Erreichbare Umweltvorteile

Geringere Verschmutzung des Abwassers. Weniger Abfälle, z. B. bei Verwendung als Tierfutter.

### Betriebsdaten

Es wird berichtet, dass sich die Abwasserbelastung wegen des sehr hohen CSB-Gehalts und der Neigung zur Bildung organischer Säuren erheblich erhöht, wenn Brauereihefe in die Kläranlage entsorgt wird.

In einer Beispielbrauerei wurde festgestellt, dass mit dem Abwasser Bier im Wert von über 1 Mio. GBP/Jahr verloren gingen. Eine Prüfung zur Minimierung des Abfalls ergab, dass 80% aller Bierverluste in einem Gefäß auftraten, in dem das Bier von den Brauereihefezellen getrennt wurde. Das klare Bier lief durch eine feste Leitung aus dem Gefäß, bevor der Bodensatz mit den Hefezellen in den Abfluss geleitet wurde. Die Höhe der Grenzschicht zwischen den zwei Phasen war abhängig von der Biersorte, und das unterhalb des Überlaufs in die feste Leitung befindliche Bier gelangte ins Abwasser und war damit verloren. Das Verfahren wurde modifiziert, sodass nun zuerst die Hefe abgezogen wird, und zwar so lange, bis ein Kapazitätssensor im unteren Bereich des Gefäßes die Grenzschicht erkennt. Dann erst wird das Bier in den Lagertank abgepumpt.

Die Brauereihefe kann abgetrennt werden, damit sie nicht in die Kläranlage gelangt.

Abbildung 4.22 zeigt die möglichen Einsparungen an Wasser und Abwasser beim Einsatz dieser Technik und anderer Techniken in einer Brauerei.

#### Anwendbarkeit

In Brauereien, Brennereien und Weinkellereien anwendbar.

#### Wirtschaftlichkeit

Geringere Kosten für die Abwasserklärung. Geringe mögliche Kosten und hohes Amortisationspotential.

#### Anlass für die Umsetzung

Geringerer Produktverlust. Vermeidung hoher Kosten für die Abwasserklärung.

#### Beispielanlagen

In Brauereien angewandt.

#### Referenzliteratur

[1, CIAA, 2002, 11, Environment Agency of England and Wales, 2000, 23, Envirowise (UK) and Dames & Moore Ltd, 1998]

### **4.7.9.4 Filtration**

#### **4.7.9.4.1 Membranfiltration des Produktes**

##### Beschreibung

Während der Herstellung von Getränken wird in verschiedenen Prozessstufen filtriert, z. B. beim Schönen und vor dem Abfüllen, um restliche Feststoffe, unlösliche trübende Substanzen und Mikroorganismen zu entziehen. Zur Verringerung des Wasserverbrauchs und der Abwassermengen kann ein Membrantrennverfahren anstelle der Filtration durch natürliche mineralische Adsorptionsmaterialien wie Kieselgur angewandt werden. Damit entfällt auch die Gefahr, dass Filterkuchen oder abgetrennte Feststoffe mit dem Waschwasser mitgerissen werden und das Abwasser zusätzlich belasten. Das verbrauchte Filtermaterial kann entwässert werden. Je nach Zusammensetzung wird berichtet, dass es kompostiert oder im Weinberg ausgebracht oder destilliert wird. Es wird berichtet, dass bei der Behandlung und Rückgewinnung von Kieselgur Probleme auftreten. Mit dieser Technik werden eine intensive Filtration des Produktes ermöglicht und restliche Mikroorganismen und andere suspendierte Teilchen entzogen. Sie wird auch als Sterilisationsverfahren eingesetzt.

##### Erreichbare Umweltvorteile

Verringerung von Wasserverbrauch, Abwasserkontamination und Wegfall der Probleme, die bei der Entsorgung von Kieselgur auftreten.

##### Anwendbarkeit

Anwendbar in Anlagen zur Herstellung von Getränken, sofern durch intensive Filtration des Produktes dessen Qualität nicht beeinträchtigt wird. Diese Technik wird nicht für die Schönung in Brauereien benutzt, ihre Anwendung dafür befindet sich aber in der Entwicklung. Es treten Probleme im Zusammenhang mit der erwünschten Schaumbildung des Endproduktes auf.

##### Beispielanlagen

Wird in Anlagen eingesetzt, die Wein und alkoholfreie Getränke verarbeiten.

##### Referenzliteratur

[134, AWARENET, 2002]

#### **4.7.9.4.2 Cross-Flow-Filtration**

##### Beschreibung

Eine Cross-Flow-Filtration ist ein Verfahren, bei dem der Zustrom parallel zur Membran fließt. Der Zustrom muss unter Druck stehen. Das Prinzip ist in Abbildung 4.76 dargestellt.

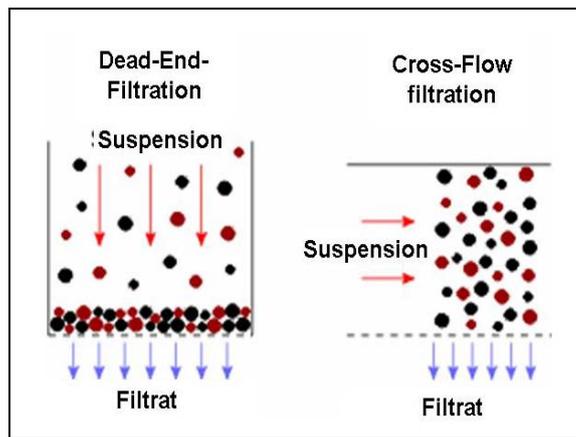


Abbildung 4.76: Prinzip der Cross-Flow-Filtration im Vergleich zur Dead-End-Filtration

Das Cross-Flow-Prinzip kann je nach Porengröße der Membran in der Umkehrosmose, der Nanofiltration, der Ultrafiltration und der Mikrofiltration angewandt werden (siehe auch Abschnitt 4.5.4.6).

### Erreichbare Umweltvorteile

Bei einer Cross-Flow-Filtration kann der Zustrom wiederverwertet und Material rückgewonnen werden.

### Medienübergreifende Effekte

Energieverbrauch.

### Betriebsdaten

Die Cross-Flow-Filtration hat einen hohen Energieverbrauch, da der gesamte Zustrom unter Druck stehen muss. Im Vergleich zur Dead-End-Filtration, bei der das gesamte Wasser durch den Filter läuft und die Rückstände sich auf dem Filter sammeln, hat die Cross-Flow-Filtration den Vorteil eines geringeren Foulings. Der Filter ist gegenüber Fouling relativ resistent und kann leicht gereinigt werden.

Es wird berichtet, dass der größte Vorteil der Cross-Flow-Filtration bei der Weinherstellung darin liegt, dass fast alle Bakterien aus dem Wein entfernt werden. In einer Studie wurde gezeigt, dass unfiltrierter Wein eine hohe Keimzahl aufweisen und bei höheren Temperaturen entsprechend verderbsanfälliger sind. Bei einer Cross-Flow-Filtration durch eine Membran mit einer Porengröße von  $0,22\ \mu\text{m}$  wurden fast alle Bakterien entfernt und damit die Gefahr des bakteriellen Verderbs der Weine bei höheren Temperaturen ausgeschlossen. Die geringen Veränderungen beim Alkoholgehalt, beim Gehalt an titrierbarer Säure, im Extrakt und in der Farbe, die durch die Cross-Flow-Filtration hervorgerufen werden, lassen sich dadurch erklären, dass die Weine sauberer sind als die entsprechenden nicht filtrierten Weine. Oxidative Veränderungen der Weine durch die Cross-Flow-Filtration wurden nicht festgestellt. Bei der sensorischen Prüfung von Weinen der Sorten Pinotage, Shiraz und Cabernet Sauvignon wurden keine signifikanten Unterschiede festgestellt zwischen unfiltrierten Weinen und Weinen, die einer Cross-Flow-Filtration unterzogen worden waren.

### Anwendbarkeit

Breiter Anwendungsbereich der Nahrungsmittelproduktion.

### Beispielanlagen

In Brauereien, Weinkellereien, Molkereien und Kläranlagen anwendbar.

### Referenzliteratur

[13, Environment Agency of England and Wales, 2000, 23, Envirowise (UK) and Dames & Moore Ltd, 1998, 236, Ellis L., 2002]

#### **4.7.9.4.3 Rückgewinnung von Filtermaterial, wenn das Produkt durch natürliche mineralische Adsorptionsmaterialien gefiltert wird**

### Beschreibung

Während der Herstellung von Getränken wird in verschiedenen Prozessstufen filtriert, z. B. beim Schönen und vor dem Abfüllen, um restliche Feststoffe, unlösliche trübende Substanzen und Mikroorganismen zu entziehen.

Die Filtration durch natürliche mineralische Stoffe wie Bentonit und Kieselgur ist nur eine Grobfiltration, bei der einige Stoffe im Produkt verbleiben. Es wird berichtet, dass dieses Verfahren die Weinqualität verbessert. Das Filtermaterial kann gesammelt werden, damit es nicht in die Kläranlage gewaschen wird. Es wird berichtet, dass es je nach Zusammensetzung für die erneute Verwendung aufbereitet, kompostiert, im Weinberg ausgebracht oder destilliert werden kann.

#### Medienübergreifende Effekte

Sofern der Filter nicht getrennt gesammelt wird, gelangt das Material in die Kläranlage und verunreinigt das Abwasser.

#### Betriebsdaten

Aus dem Bereich der Weinherstellung wird berichtet, dass die Filtration mit natürlichen mineralischen Adsorptionsmaterialien eine hohe Weinqualität ermöglicht; je intensiver beispielsweise die Filtration ist, desto schlechter wird der Wein.

Es wird berichtet, dass Kieselgur entwässert und dann in einen Reaktor geleitet werden kann, in dem es mit einem Heißluftstrom schonend getrocknet und ausgeglimmt wird. Danach kann das Kieselgur wieder vollständig für Filtrationszwecke eingesetzt werden. Das aus dem Reaktor kommende Abgas muss behandelt werden. Da Kieselgur viele Male wiederverwendet werden kann, reduzieren sich die Kosten für die Filtration und Entsorgung.

#### Anwendbarkeit

Anwendbar in Anlagen zur Herstellung von Getränken, wenn eine Grobfiltration des Produktes erforderlich ist, z. B. in der Weinherstellung.

#### Beispielanlagen

Wird bei der Herstellung von Wein, Bier und Apfelsaft eingesetzt.

#### Anlass für die Umsetzung

Geringerer Produktverlust.

#### Referenzliteratur

[134, AWARENET, 2002, 200, CIAA, 2003, 255, Germany, 2005]

### **4.7.9.5 Abfüllung in Flaschen**

Innerhalb der Abfüllung ist die Flaschenreinigungsanlage der größte Verbraucher von Frischwasser und damit auch der größte Abwassererzeuger.

#### **4.7.9.5.1 Integrierte Abfüllanlage**

##### Beschreibung

In einer Beispielanlage werden Branntweine, Neutralalkohol, Getreidespirituosen, Essenzen sowie destillierter Rum und Whisky hergestellt. Die jährliche Produktionsmenge beträgt 70 Million 0,7-l-Standardflaschen. Zur Verringerung des Energieverbrauchs wurde eine neue Flaschenabfülllinie installiert.

Derzeit wird die angelieferte Rohware auf die Einhaltung der Qualitätsvorgaben überprüft. Vor der Verarbeitung werden die flüssigen Rohstoffe in großen Stahltanks, die festen Rohstoffe auf Paletten gelagert. Die Rohstoffe werden dann entsprechend der jeweiligen Rezeptur gemischt. Dies geschieht in Spezialtanks. Die Dosierung aller Rohstoffe einschließlich des vorbehandelten Produktwassers wird über das Gewicht und mit Hilfe eines Computersystems gesteuert. Zur Entfernung der suspendierten Feststoffe werden die Ansätze dann in Bettfiltern filtriert. Für die einzelnen Spirituosen werden unterschiedliche Filterbetten mit unterschiedlicher Trennschärfe eingesetzt. Nach einer Qualitätsprüfung im Analyselabor wird das fertig gemischte und gefilterte Produkt zur Abfülllinie geleitet. Abbildung 4.77 zeigt ein Fließbild dieses Verfahrens.

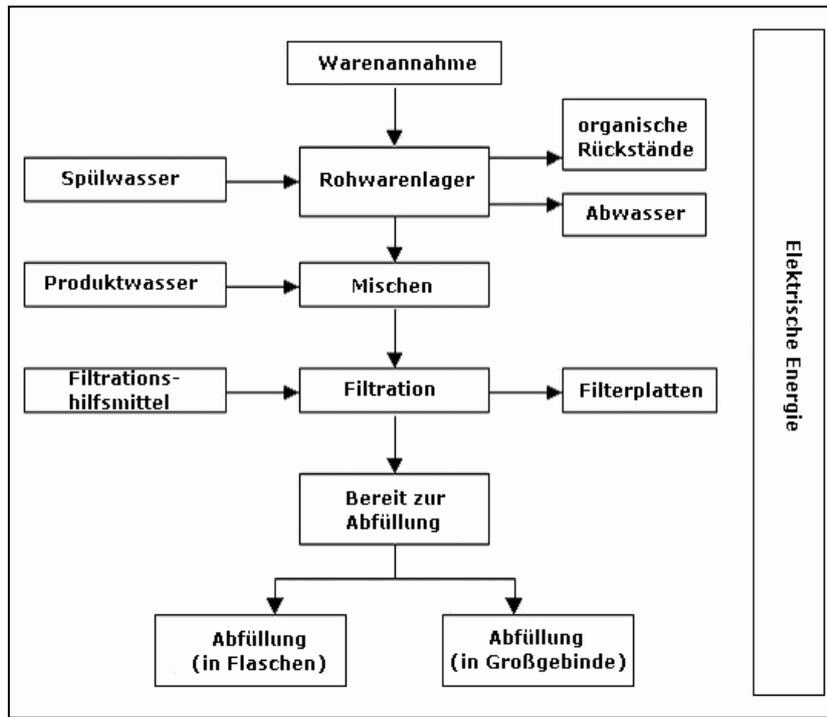


Abbildung 4.77: Fließbild der Herstellung alkoholischer Getränke

Die Abfülllinie ist in Abbildung 4.78 dargestellt.

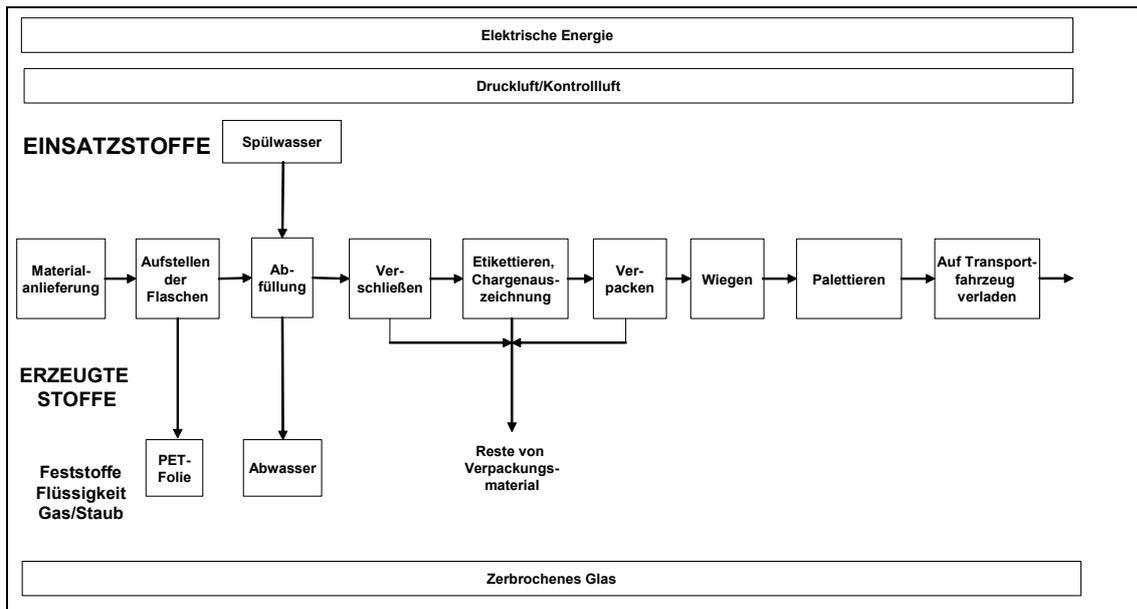


Abbildung 4.78: Fließbild der Abfülllinie

Im ersten Schritt beliefern Staplersysteme die einzelnen Einheiten mit Paletten, auf denen sich leere Flaschen und Kartons befinden. Sie werden auch für die Verschlüsse und Etiketten eingesetzt, die bei der Abfüllung und Verpackung benötigt werden. Die Paletten mit den leeren Flaschen werden auf Förderbänder gesetzt, die Schutzfolie aus Kunststoff wird von Hand entfernt. Die Paletten gelangen in die Abschiebestation. Dort gleiten die leeren Flaschen lagenweise von den Paletten, werden dann auf den Flaschenförderbändern in einer Reihe nacheinander angeordnet und zu den Abfülleinheiten transportiert. Die Kunststofffolie wird gesammelt, zu Ballen gepresst und an ein Recyclingunternehmen weitergegeben.

Die leeren Flaschen werden in der Umlauffüllereinrichtung gefüllt und dann verschlossen. Die erste gefüllte Flasche wird immer untersucht. Die Abfüllung der anderen Flaschen beginnt erst nach der Freigabe durch das Labor. Inspektionssysteme an den Abfülleinrichtungen überwachen Füllstand und Verschluss der Flaschen.

Nicht ausreichend gefüllte oder unverschlossene Flaschen werden automatisch ausgeschleust. Die gefüllten Flaschen werden dann zur Etikettierstation transportiert. Es werden sowohl Etiketten aus selbstklebender Kunststofffolie als auch herkömmliche Papieretiketten verwendet. Die vorgeschriebenen Informationen zur Identifikation der Chargen werden mit Tintenstrahldruckern angebracht.

Danach werden die gefüllten Flaschen verpackt. Es gibt zwei verschiedene Arten von Verpackungsmaschinen, die entweder nach dem Prinzip der Einschlagverpackung oder nach dem Prinzip des Faltkartons arbeiten. Bei der Einschlagverpackung werden vier Arbeitsabläufe in einem Verfahren abgewickelt. Hierbei wird der Karton aufgefaltet, der Inhalt eingelegt, der Karton verschlossen und weitertransportiert. Man benötigt nur eine Maschine und nicht vier.

Der volle Karton kann etikettiert werden und wird dann über eine Kartonwaage dem Palettiersystem zugeführt. Die Kartonwaage stellt eventuelle Abweichungen vom Zielgewicht fest und schleust die entsprechenden Kartons als Ausschuss aus dem Verfahren aus. Nach dem Wiegen werden die Kartons automatisch auf „Euro-Paletten“ gestapelt. Die mit Kartons gefüllter Flaschen beladenen Paletten werden dann mit Stretchfolie umwickelt, damit beim weiteren Transport mehr Sicherheit für die Ladung besteht.

Da es in dieser Anlage kein internes Fertigwarenlager vor Ort gibt, wird die gesamte Produktionsmenge im Pendelverkehr zu einem externen Logistiklager gebracht. Es können zwei Pendelfahrzeuge gleichzeitig an den Beladestationen andocken und innerhalb von drei Minuten mit jeweils 30 Paletten beladen werden. Dabei werden keine Gabelstapler eingesetzt.

#### Erreichbare Umweltvorteile

Erheblich geringerer Energieverbrauch. Verringerte Lärmemissionen.

#### Medienübergreifende Effekte

Abwasser entsteht z. B. bei der Herstellung, Reinigung und beim Spülvorgang. Es entsteht Abfall, z. B. PET-Folie, Reste von Verpackungsmaterial und Glasbruch.

#### Betriebsdaten

Die neue Abfülllinie verbraucht im Durchschnitt pro 1.000 Standardflaschen 1,0 bis 1,5 kWh weniger Energie als die alte Linie (hier nicht beschrieben). Durch den Pendeltransport werden im Vergleich zum Transport der vollen Paletten mit Gabelstaplern 15.600 l Dieselkraftstoff eingespart. Tabelle 4.116 zeigt die Verbrauchs- und Emissionswerte der Abfülllinie im Jahr 2000. Tabelle 4.117 zeigt die Werte für Produktion, Energieverbrauch und Abwasser in den Jahren 1999 bis 2001.

| Parameter  | Einheit                                  | Menge         |
|--|--|---------------|
| Wasserverbrauch  | m <sup>3</sup>                           | 38.830        |
| Davon in Produkt                                       | m <sup>3</sup>                           | 25.600        |
| Energieverbrauch                                       |  |               |
| Fossile Energie/Heizöl                                 | MWh                                      | 1.942,9       |
| Elektrische Energie                                    | MWh                                      | 2.316,6       |
| Spezifischer Energieverbrauch (bezogen auf Endprodukt) | kWh/10 <sup>3</sup> Flaschen             | 9,4           |
| Produktion   |  |               |
| Vinasse  | Tonnen                                   | 3.539         |
| Pottasche aus Vinasse                                  | Tonnen                                   | 754           |
| Abfall   |  |               |
| Karton/Papier  | Tonnen                                   | 258           |
| Restmetall   | Tonnen                                   | 10            |
| Glasbruch  | Tonnen                                   | 157           |
|  | kg/10 <sup>3</sup> Flaschen              | 3,5 – 4,0     |
| PET-Folie  | Tonnen                                   | 113           |
|  | kg/10 <sup>3</sup> Flaschen              | 1,0 – 1,2     |
| Abwasser   |  |               |
| Volumen  | m <sup>3</sup>                           | 13.230        |
|  | m <sup>3</sup> /10 <sup>3</sup> Flaschen | 0,199         |
| CSB-Gehalt   | mg/l                                     | 1.900 – 5.400 |
| BSB <sub>5</sub> -Gehalt                               | mg/l                                     | 1.200 – 3.000 |
| pH-Wert  |  | 7,7 – 8       |

Tabelle 4.116: Verbrauchs- und Emissionswerte der Abfülllinie (2000)

| Parameter                            | Einheit                      | 1999      | 2000      | 2001 (bis Nov.) |
|--------------------------------------|------------------------------|-----------|-----------|-----------------|
| Gesamtproduktion                     | 10 <sup>3</sup> Flaschen     | 69.636    | 66.465    | 62.083          |
| Produktion mit der neuen Technik     | 10 <sup>3</sup> Flaschen     | 47.256    | 48.072    | 47.189          |
| Gesamtstromverbrauch                 | kWh                          | 2.282.840 | 2.316.640 | 2.097.560       |
| Stromverbrauch mit der neuen Technik | kWh                          | 462.928   | 469.502   | 442.830         |
| Gesamtstromverbrauch                 | kWh/10 <sup>3</sup> Flaschen | 32,8      | 34,8      | 33,8            |
| Stromverbrauch mit der neuen Technik | kWh/10 <sup>3</sup> Flaschen | 9,8       | 9,8       | 9,4             |
| Brennstoff (Heizölverbrauch)         | kWh                          | 2.065.620 | 1.942.920 | 1.606.480       |
|                                      | kWh/10 <sup>3</sup> Flaschen | 29,7      | 29,2      | 25,9            |
| Abwasseranfall                       | m <sup>3</sup>               | 17.292    | 13.229    |                 |
|                                      | hl/10 <sup>3</sup> Flaschen  | 2,48      | 1,99      |                 |

Tabelle 4.117: Werte für Produktion, Energieverbrauch und Abwassermenge einer Anlage zur Produktion alkoholischer Getränke von 1999 bis 2001.

| Angewandte Technik  | Energieverbrauch<br>(kWh/10 <sup>3</sup> Flaschen) |              |           |
|---|--|--------------|-----------|
|   | Produktionseinheiten                               | Etikettieren | Verpacken |
| Veraltete Technik<br>(Durchschnitt 10<br>Jahre)                     | 8,2 – 8,4  | 0,38         | 2,77      |
| Moderne und veraltete<br>Technik insgesamt<br>(weniger als 6 Jahre) | 7,3 – 7,6  | 0,36         | 0,91      |
| Moderne Technik   | 5,9 – 6,5  | 0,3          | 0,61      |
| Veraltete Technik   | 1,1 – 1,4  | 0,06         | 0,3       |

**Tabelle 4.118: Vergleich alter und neuer Technik in Bezug auf den durchschnittlichen Energieverbrauch**

Da die neuen mechanischen Systeme glatter laufen, nehmen auch die Lärmemissionen ab.

#### Anwendbarkeit

Anwendbar in Flaschenabfüllanlagen.

#### Wirtschaftlichkeit

Das vollautomatische Pendelsystem spart im Vergleich zum Einsatz von Gabelstaplern hohe laufende Kosten und betriebliche Ressourcen. Neben dem geringeren Ressourcenverbrauch hat die technische Modernisierung wegen des höheren stündlichen Ausstoßes erhebliche wirtschaftliche Auswirkungen. Das ist einer der Gründe für die 10%ige Verringerung der Produktionskosten pro Standardflasche und die 7,5%ige Produktivitätszunahme im Vergleich von 1999 bis 2001.

#### Beispielsanlagen

Eine Anlage zur Herstellung alkoholischer Getränke in Deutschland.

#### Referenzliteratur

[65, Germany, 2002]

### 4.7.9.5.2 Mehrstufige Flaschenreinigung

#### Beschreibung

Durch die Kombination unterschiedlicher Verfahren in den verschiedenen Zonen der Reinigungsmaschine kann eine Einsparung im Wasserverbrauch erreicht werden. Die verschiedenen Verfahrensschritte sind in einem einzigen System zusammengefasst. Die Basisformel zur Berechnung des Umfangs der notwendigen Reinigung lautet:

$$\text{Reinigung} = \text{Temperatur} \times \text{Zeit} \times \text{Konzentration} \times \text{mechanische Kraft}$$

mit

Konzentration = Gehalt an Chemikalien

Mechanische Kraft = Stärke der mechanischen Reinigung, z. B. der Sprühdüsen

Bis zu einem gewissen Grad werden diese Parameter durch die Ausgestaltung der Reinigungsmaschine bestimmt. Andere Mengen wie Art und Konzentration der benutzten Chemikalien, Zusatzstoffe und oberflächenaktiven Substanzen werden in Zusammenarbeit mit dem Lieferanten dieser Produkte optimiert. Bei dem Reinigungsvorgang, der in erster Linie in der Einweichzone und im Laugenbad stattfindet, werden die Flaschen keimfrei gemacht. Das Zusammenspiel aus chemischer, thermischer und mechanischer Wirkung stellt sicher, dass die Flaschen innerhalb einer bestimmten Zeit gereinigt werden.

In Abbildung 4.80 ist das Verfahren der Flaschenreinigung schematisch dargestellt. Die Flaschen durchlaufen die einzelnen Bereiche der Flaschenreinigungsmaschine in der in Abbildung 4.79 dargestellten Reihenfolge.

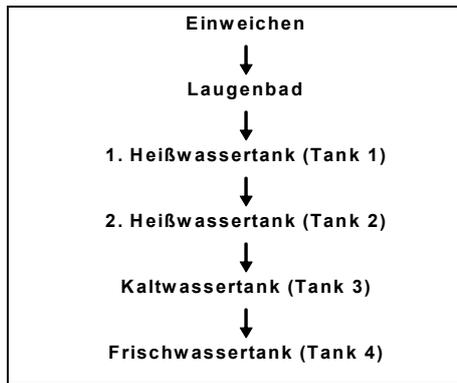


Abbildung 4.79: Einzelne Stufen der Flaschenreinigung und -spülung

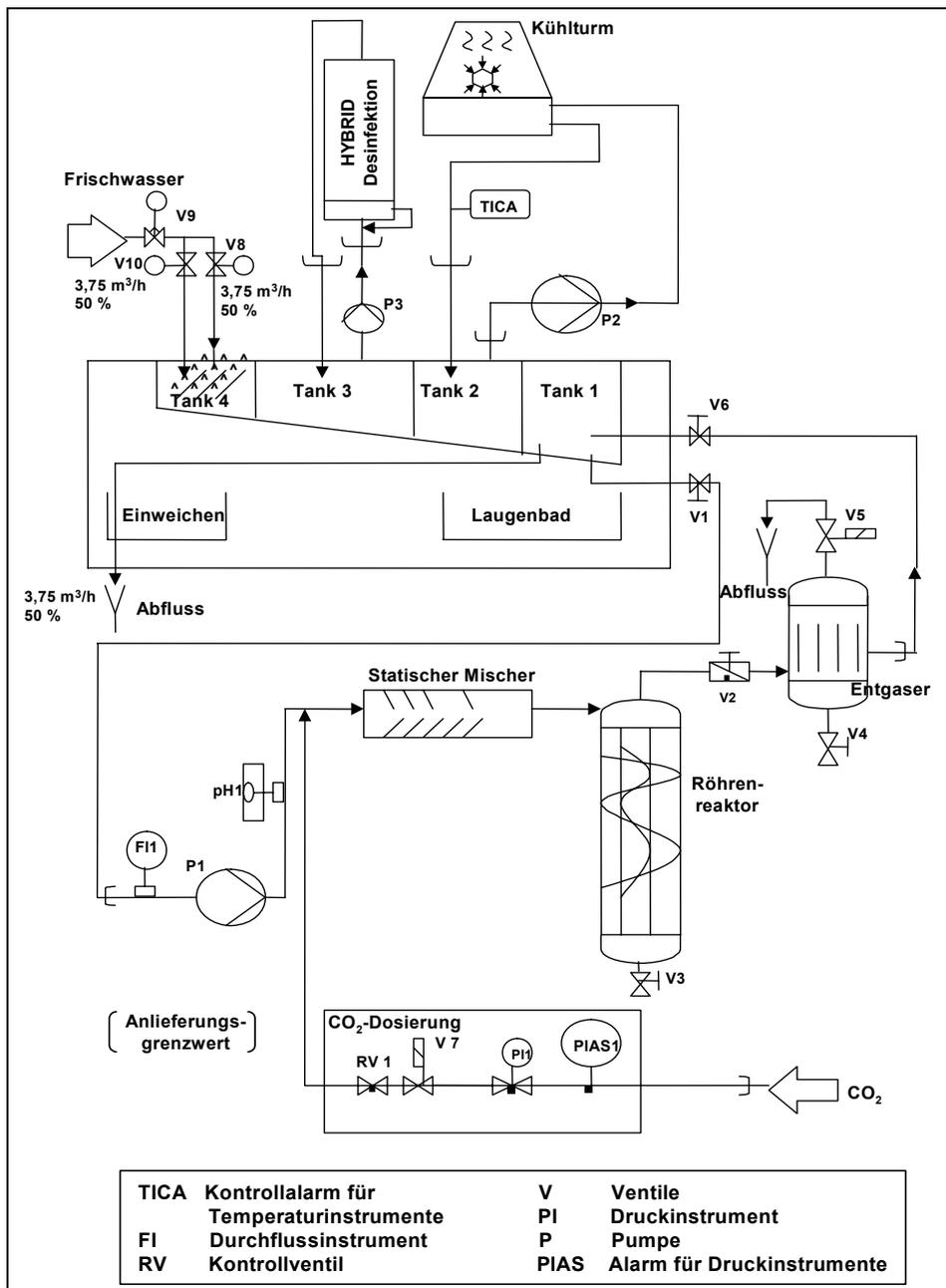


Abbildung 4.80: Verfahren zur Flaschenreinigung mit Überwachung des pH-Wertes zwecks Reduzierung des Wasserverbrauchs<sup>37</sup> [65, Germany, 2002]

<sup>37</sup> Anm. d. Übers.: Im engl. Text steht "RV ... value" statt valve, gemeint ist aber sicher valve = Ventil.

Im Laugenbad werden die Glasflaschen mit etwa 1,8%iger Natronlauge gereinigt. Die beim Verlassen des Laugenbads in den Flaschen enthaltenen Reste von Lauge, Chemikalien und Schmutzteilchen müssen dann in den nachfolgenden Reinigungszoneen gewaschen werden. Die Schmutzteilchen, die aus dem Laugenbad mitgeschleppt wurden, können problemlos in den ersten Sprühzoneen abgespült werden. Erheblich schwieriger ist die Beseitigung der mit den Flaschen in die erste Heißwasserzone (Tank 1) eingetragenen Alkalinität. Wenn die Flaschen das Laugenbad verlassen, sind sie noch von der Reinigungslösung benetzt, die dann mitgetragen wird.

Der pH-Wert im ersten Becken nach dem Laugenbad liegt anfänglich zwischen 10 und 11. Dieser hohe pH-Wert begünstigt die Ablagerung von Kalk und Magnesiumsalzen, d. h. das Ausfällen von Kesselstein, wenn hartes Trinkwasser verwendet wird. Durch Neutralisation des Wassers kann die Bildung von Kesselstein erheblich verringert werden.

In einer Beispielanlage wurde der pH-Wert durch Neutralisation mit Kohlendioxid auf 7,5-8 gesenkt. Der neutrale pH-Wert verbessert die Wirksamkeit der Desinfektionsmittel und senkt den Bedarf an chemischen Mitteln erheblich.

Das neutralisierte Wasser wird aus der zweiten Heißwasserzone (Tank 2) gepumpt und in den geschlossenen Kühlkreislauf zum Kühlen des Sprühwassers eingespeist. Dadurch kühlt das Reinigungswasser in dieser Zone ab. Das abgekühlte Wasser wird dann in die zweite Heißwasserzone (Tank 2) zurückgeleitet.

#### Erreichbare Umweltvorteile

Verringerung des Wasserverbrauchs und damit auch des Abwasservolumens. Geringere Kontamination des Abwassers, da weniger Chemikalien verbraucht werden. Geringerer Energieverbrauch. Weniger Aufwand für Transport, Lagerung und Umgang mit Chemikalien. Der pH-Wert des Abwassers wird optimiert.

#### Betriebsdaten

In der Beispielanlage konnte der Wasserverbrauch pro gereinigter Flasche von 530 auf 264 ml gesenkt werden, mit entsprechender Reduzierung der Abwassermenge. Der Wasserverbrauch schwankt je nach Größe und Verschmutzungsgrad der Flaschen. Neben einem hohen Wasserverbrauch hatten die älteren Flaschenreinigungsmaschinen unter anderem folgende Nachteile: Ablagerung von Kesselstein in den Heißwasserbereichen und Verschleppung von Alkalinität sowie Notwendigkeit der Verwendung teurer Komplexbildner und Desinfektionsmittel und deren mögliche Eintragung ins Abwasser. Diese Nachteile werden mit dem mehrstufigen Kombinationsverfahren beseitigt. Trotz des Rückgangs des Frischwassereinsatzes um 51% ist durch die Rückführung des gekühlten Wassers noch ein zuverlässiges Abkühlen der Flaschen gewährleistet.

#### Anwendbarkeit

Dieses System kann Flaschenreinigungsmaschinen in bestehenden Abfülllinien ersetzen. Beispielsweise kann dieses Verfahren auf alle älteren Flaschenreinigungsmaschinen angewendet werden, die mehr als 400 ml Wasser pro gereinigter Flasche verbrauchen. Beispielsweise sind 80% der Flaschenreinigungsmaschinen, die in Deutschland bei der Herstellung alkoholfreier Erfrischungsgetränke eingesetzt werden, Modelle dieser Art.

Es wird berichtet, dass zur Sicherstellung einer ausreichenden Reinigungsqualität ein angestrebter Wasserverbrauch von unter 200 ml pro gereinigter Flasche nicht realistisch ist. Neue Modelle benötigen nur 150 ml pro gereinigter Flasche. Für diese Maschinen gibt es also keine Einsparungsmöglichkeiten mehr.

#### Wirtschaftlichkeit

Um eine akzeptable Amortisation zu erreichen, muss die Wassereinsparung mindestens 200 ml pro gereinigter Flasche betragen.

#### Anlässe für die Umsetzung

Geringerer Verbrauch an Wasser, Reinigungs- und Desinfektionsmitteln und damit Kostenreduzierung.

#### Beispielanlagen

Mindestens ein Hersteller alkoholfreier Erfrischungsgetränke in Deutschland.

#### Referenzliteratur

[65, Germany, 2002]

**4.7.9.5.3 Wiederverwendung der Reinigungslösungen aus der Flaschenreinigung nach Sedimentation und Filtration**

Beschreibung

Um Natronlauge und Frischwasser zu sparen und eine unnötige Belastung des Abwassers zu vermeiden, wird die Flüssigkeit im Flaschenreinigungsbad am Ende des Produktionsverfahrens stehen gelassen, damit sich Inhaltsstoffe absetzen können, und filtriert. Die Reinigungslösung wird unter Einsatz von elektrischer Energie aus der Flaschenreinigungsanlage in einen Sedimentationstank gepumpt. Der Tank dient auch als Zwischenlager. Die sedimentierten Teilchen werden über eine Filtereinheit abgezogen, wozu ebenfalls Strom für den Pumpvorgang benötigt wird. Das Wasser steht dann zu Beginn des nächsten Produktionslaufs wieder für die Reinigung zur Verfügung.

Erreichbare Umweltvorteile

Weniger Verbrauch an Natronlauge und Frischwasser. Geringere Verschmutzung des Abwassers.

Medienübergreifende Effekte

Energieverbrauch z. B. zum Pumpen.

Betriebsdaten

In einer Beispielanlage in Deutschland wird die Reinigungslösung, d. h. 2%ige Natronlauge, während der fünf oder sechs Arbeitstage der Woche wiederverwendet. Die Lösung kann noch länger, z. B. wochenlang, benutzt werden, wenn ein Lagertank installiert ist.

Die ausgeschiedenen Stoffe, z. B. Abwasser und Sediment, die nicht wiederverwendet werden, werden mit Kohlensäure neutralisiert. Alternativ kann auch Schwefelsäure (H<sub>2</sub>SO<sub>4</sub>) eingesetzt werden. Die Verwendung von Salzsäure (HCl) kann zur Entstehung von Säuredämpfen führen. Liegt der pH-Wert unterhalb von 10, ist eine Neutralisation in der Regel nicht notwendig. Wird die Neutralisation mit CO<sub>2</sub> durchgeführt, muss eine Belüftungsanlage im Raum installiert sein.

Abbildung 4.81 zeigt das CIP-System für ein Abfüllverfahren in einer Brauerei.

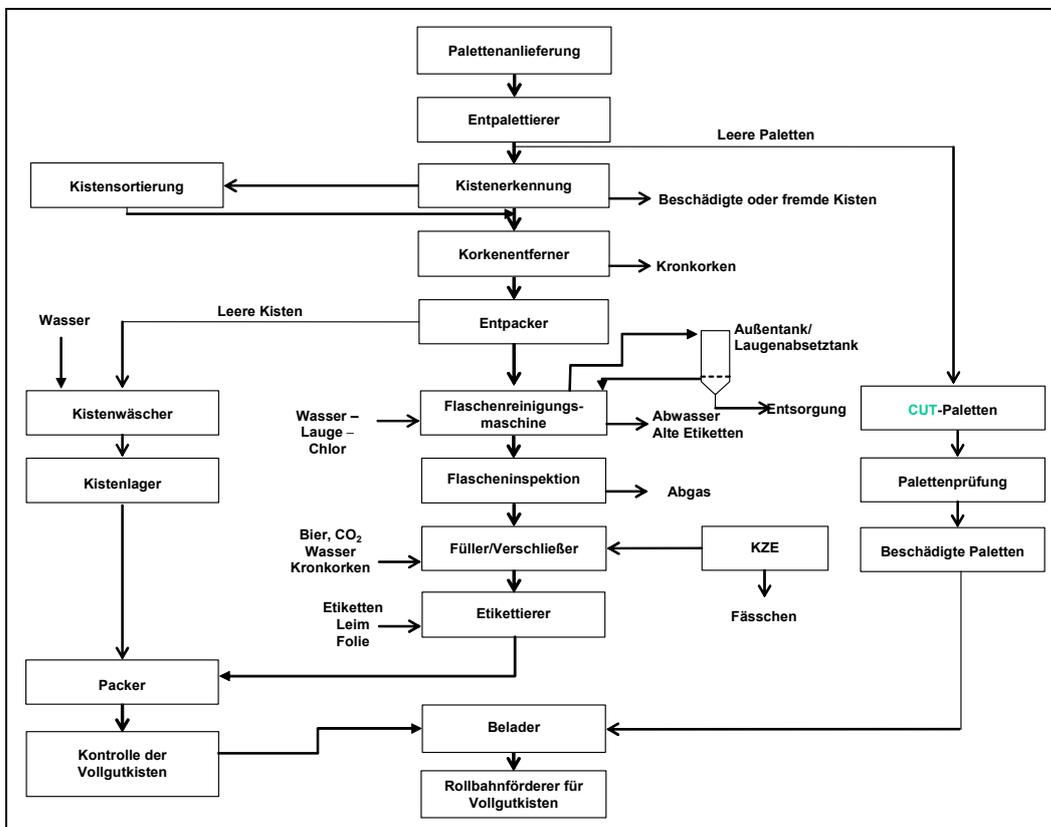


Abbildung 4.81: CIP-System für ein Abfüllverfahren in einer Brauerei.

Wirtschaftlichkeit

Kosteneinsparungen für Wasser und Natronlauge. Geringere Kosten für die Abwasserklärung.

Anlässe für die Umsetzung

Kosteneinsparung.

Referenzliteratur

[65, Germany, 2002]

**4.7.9.5.4 Optimierung des Wasserverbrauchs bei der Flaschenreinigung**Beschreibung

In einer Beispielbrauerei in Dänemark wird die Spülwassermenge bei der Flaschenreinigung gemessen (siehe Abschnitt 4.1.8.4); die Wasserzufuhr wird durch automatische Ventile unterbrochen, sobald die Linie stoppt (siehe Abschnitt 4.1.8.7). In den letzten zwei Reihen der Spüldüsen wird Frischwasser verwendet.

Das letzte Spülwasser kann zum Vorspülen oder in anderen Stufen der Reinigung von Flaschen, Dosen oder anderen Behältern wiederverwendet werden. Werden für das Abfüllverfahren Wasserring-Vakuumpumpen eingesetzt, so kann die Kontamination des Sperrwassers derart minimiert werden, dass die Wiederverwendung dieses Wassers als Spülwasser möglich ist.

Erreichbare Umweltvorteile

Verringerung von Wasserverbrauch und Abwasserkontamination.

Betriebsdaten

Eine Beispielbrauerei meldete einen Wasserverbrauch von etwa 0,5 hl/hl Bier<sup>38</sup>.

Anwendbarkeit

Anwendbar für alle Anlagen aus dem Bereich der Nahrungsmittelproduktion, in denen Flaschen für die Befüllung gereinigt werden, z. B. zum Abfüllen von konservierten Lebensmitteln, alkoholfreien Erfrischungsgetränken, bei der Weinherstellung, in Brauereien und Molkereien.

Beispielanlagen

Mindestens eine Brauerei in Dänemark.

Referenzliteratur

[13, Environment Agency of England and Wales, 2000, 59, Danbrew Ltd., 1996]

**4.7.9.5.5 Wiederverwendung des Wassers aus der Flaschenpasteurisation**Beschreibung

Um den Wasserverbrauch zu senken, wird das aus den Pasteurisatoren überlaufende Wasser in Edelstahltanks gesammelt. Das gesammelte Wasser wird dann zu einem Kühlturm geleitet und danach mit voreingestelltem Druck und nach Zugabe von z. B. Korrosionshemmern und Bioziden wieder dem Pasteurisator zugeführt.

Erreichbare Umweltvorteile

Verringerung des Verbrauchs an Wasser und Chemikalien. Geringere Abwassermenge.

Medienübergreifende Effekte

Mögliche Übertragung von Legionellen (Legionärskrankheit), Korrosion oder Bildung von Kesselstein.

Betriebsdaten

In einer Beispielanlage, in der Bier abgefüllt wird, wurden 51% des gesamten Wasserverbrauchs von etwa 7.000 m<sup>3</sup>/Woche für die Pasteurisation verbraucht. Obwohl die Pasteurisatoren so ausgelegt waren, dass regenerative Ströme genutzt werden konnten, gab es eine stetige Nachfrage nach Kühlwasser, das dann in den Abfluss überlief. Der durchschnittliche Abfluss betrug 10 m<sup>3</sup>/Std., mit Spitzenwerten von etwa 60 m<sup>3</sup>/Std. Dieser stetige Abfluss zur Kläranlage führte zu Verlusten an korrosionshemmenden und biozid wirkenden Stoffen. Zusätzlich

<sup>38</sup> Anm. d. UBA-Bearb.: Deutsche Beispiele wurden hier nicht berücksichtigt. In D liegen die Werte bei 0,35 hl/hl Bier.

traten noch Verdunstungsverluste aus den Kühltürmen in der Größenordnung von 5% auf, die ebenfalls zusätzliche Wassermengen erforderlich machten. Nach der Installation einer Einrichtung zur Wasserrückgewinnung aus den Pasteurisatoren auf dem Dach des Gebäudes konnte der Gesamtwasserverbrauch am Standort um 17% gesenkt werden. Es wurden Einsparungen von 80% bei Wasser und Abwasser und 23% bei den Chemikalien erreicht.

In dieser Beispielanlage wird die Abfüllung in Flaschen und Dosen getrennt gehalten, denn geborstene Flaschen im Pasteurisator können häufig zu Produktaustritten führen, z. B. Bier in das Wasser des Pasteurisators.

### Anwendbarkeit

Dieses System kann für Pasteurisatoren, Vakuumpumpen und Autoklaven verwendet werden.

### Wirtschaftlichkeit

In einer Beispiel-Verpackungsanlage fielen Kosten für das Zusatzwasser von etwa 0,80 EUR/m<sup>3</sup> plus 1,10 EUR/m<sup>3</sup> für einen stetigen Abfluss zum Klärwerk an. Das entspricht 7,20 - 43,20 EUR, die pro Stunde für jeden der vier Pasteurisatoren verloren wurden. Die Kapitalkosten beliefen sich auf 162.000 EUR mit einer Amortisation von etwa 15 Monaten.

### Beispielanlagen

Eine Abfüllanlage in Großbritannien.

### Referenzliteratur

[13, Environment Agency of England and Wales, 2000, 94, Environment Agency of England and Wales, 2002]

#### **4.7.9.6 Brauwirtschaft**

In einer Brauerei wird Wasser hauptsächlich für das Maischen, die Wärmeübertragung und für Reinigungsvorgänge benötigt. Der Wasserverbrauch in modernen Brauereien liegt in der Regel zwischen 4 und 10 hl pro hl Bier. Tabelle 4.119 zeigt die angegebenen Einsparmöglichkeiten beim Wasser und Abwasser in einer Brauerei. Tabelle 4.120 zeigt Beispiele für normalerweise erzielbare Einsparungen beim Wasserverbrauch.

| Maßnahme   | Verfahren                                       | Beschreibung/Zweck   | Technische Ausrüstung               | Hauptvorteile                        | Weitere Vorteile                         | Mögliche Kosten <sup>1</sup> | Mögliche Amortisation <sup>2</sup> |
|--|---|--|-------------------------------------|--------------------------------------|--|------------------------------|------------------------------------|
| Flüssigkeitsmessung                                  | Messung und Schulung                            | Vermeidung überschüssiger Würzeproduktion                        | Messeinrichtung                     | Einsparungen bei Wasser und Abwasser | Einheitliche Qualität der Würze          | hoch                         | mittel                             |
| Entsorgung von Würze                                 | Lagerung und Entsorgung                         | Geringerer CSB-Wert im Abwasser                                  | Tank                                | Einsparungen beim Abwasser           |  | gering                       | kurz                               |
| Trockenhalten des Biertreibers                       | Schulung  | Minimierung des Auswaschens während Lagerung und Transport       | Bürsten (führt zu Staubentwicklung) | Einsparungen beim Abwasser           | Bessere Körnung                          | gering                       | mittel                             |
| Reinigung von Maischebottich und Kupferleitungen     | Hochdruckschlauch                               | Geringerer Wasserverbrauch als bei manueller Reinigung           | Druckreiniger                       | Einsparungen bei Wasser und Abwasser | Bessere Sauberkeit                       | mittel                       | mittel                             |
| Würzekochung   | Verkürzung der Kochzeit                         | Weniger Dampfverbrauch   | Schulung                            | Kosten- und Energieeinsparungen      |  | gering                       | lang                               |
| Rückgewinnung des Kondensats aus den Kupferleitungen | Wärmetauscher                                   | Rückgewinnung von Abwärme und Reduzierung der Geruchsentwicklung | Wärmetauscher                       | Lieferung heißer Flüssigkeit         | Energieeinsparungen, weniger Dampfabgabe | hoch                         | lang                               |
| Entsorgung des Trubs                                 | Lagerung und Entsorgung                         | Geringerer CSB-Wert im Abwasser                                  | Tank                                | Einsparungen beim Abwasser           |  | gering                       | kurz                               |
| Automatisierung der Wärmetauscher                    | Steuerventile an der Temperaturkontrolle        | Optimierung der Kühlung und der Produktion heißer Flüssigkeiten  | Ventile und Kontrolleinrichtungen   | Einsparungen bei Wasser und Abwasser | Einheitliche Kühlung der Würze           | mittel                       | lang                               |
| Optimierung der Wärmetauscher                        | Minimierung der Lagerzeit für kalte Flüssigkeit | Vermeidung der Herstellung besonders heißer Flüssigkeiten        | Schulung                            | Einsparungen bei Wasser und Abwasser | Würze für Fermenter nicht mehr so heiß   | gering/mittel                | mittel                             |
| Lagerung heißer Flüssigkeiten                        | Kapazitätssteigerung                            | Vermeidung des Überlaufens des Heißtanks                         | Neuer Tank                          | Einsparungen bei Wasser und Abwasser |  | hoch                         | lang                               |
| Kühlung des Fermenters                               | Kühlmantel oder Kühlpaneele                     | Bessere Reinigungseffizienz                                      | Neuer Bottich oder neue Kühlpaneele | Einsparungen bei Wasser und Abwasser | einfachere Reinigung                     | hoch                         | lang                               |
| Kühlung des Fermenters                               | geschlossener Kühlkreislauf                     | Verringerung des Wasserverbrauchs                                | Kühler und Umlaufpumpe              | Einsparungen bei Wasser und Abwasser | Bessere Kühlung                          | mittel                       | kurz                               |

| Maßnahme                 | Verfahren                      | Beschreibung/Zweck                                    | Technische Ausrüstung     | Hauptvorteile                        | Weitere Vorteile | Mögliche Kosten <sup>1</sup> | Mögliche Amortisation <sup>2</sup> |
|--------------------------|--------------------------------|---|---------------------------|--------------------------------------|------------------|------------------------------|------------------------------------|
| Reinigung des Fermenters | Schulung, Einsatz von Schabern | Geringere Wasser- und Abwassermengen                  | Schulung/Reinigungsgeräte | Einsparungen bei Wasser und Abwasser |                  | mittel                       | kurz                               |
| Entsorgung von Hefe      | Lagerung und Entsorgung        | Geringerer CSB-Wert im Abwasser                       | Tank                      | Einsparungen beim Abwasser           |                  | gering                       | kurz                               |
| Filtration des Biers     | Cross-Flow-Filtration          | Weniger Wasserverbrauch, geringer belastetes Abwasser | Firmeneigene Ausrüstung   | Einsparungen bei Wasser und Abwasser | Weniger Trübung  | hoch                         | mittel/lang                        |

*Mögliche Kosten und Amortisationszeiten dienen nur zur Orientierung. Die tatsächlichen Kosten und Amortisationszeiten hängen von der jeweiligen Anlage ab.*  
<sup>1</sup> Mögliche Kosten: Gering = geringfügige Veränderungen bei den Verfahren oder bestehenden Anlagen (Kosten zwischen 0 und wenigen Hundert EUR); mittel = bestimmte Veränderungen der bestehenden Anlagen oder kleinere neue Anlagen (Kosten zwischen 200 und 1.500 EUR); hoch = erhebliche Veränderungen oder neue Anlagen (mehrere Tausend EUR).  
<sup>2</sup> Mögliche Amortisation: Kurz = Monate, mittel = weniger als ein Jahr, lang = mehr als ein Jahr.

**Tabelle 4.119: Einsparmöglichkeiten bei Wasser und Abwasser in einer Brauerei [23, Envirowise (UK) and Dames & Moore Ltd, 1998]**

| Wassersparmaßnahme                                | Typische Verringerung des Prozessverbrauchs (%) | Mögliche Anwendung       |
|---|---|--------------------------|
| Wasserwiederverwertung im geschlossenen Kreislauf | bis zu 90                                       | Kühler des Fermenters    |
| CIP   | bis zu 60                                       | (neu)                    |
| Wiederverwendung von Reinigungswasser             | bis zu 50                                       | Reinigung der Fässer     |
| Spülung im Gegenstromverfahren                    | bis zu 40                                       | CIP                      |
| Gute handwerkliche Praxis                         | bis zu 30                                       | Schläuche                |
| CIP   | bis zu 30                                       | CIP-Optimierung          |
| Aufrüstung von Sprüh-/Spreitzdüsen                | bis zu 20                                       | Reinigung der Fässer     |
| Bürsten/Abzieher                                  | bis zu 20                                       | Reinigung des Fermenters |
| Automatische Abschaltung                          | bis zu 15                                       | Kühlwasserpumpe          |

Tabelle 4.120: Normalerweise erzielbare Einsparungen beim Wasserverbrauch in Brauereien

#### 4.7.9.6.1 Maischen

Das individuell eingesetzte Maischeverfahren ist unter anderem abhängig von der Malzqualität und der Art des hergestellten Bieres. Die Wahl des Maischeverfahrens beeinflusst den Energieverbrauch im Sudhaus und damit in der gesamten Brauerei.

#### 4.7.9.6.2 Maischen nach dem Infusionsverfahren

##### Beschreibung

Geschrotetes Malz wird gemeinsam mit warmem Brauwasser in den Maischebottich gegeben. Diese sogenannte Maische wird unter ständigem Rühren auf 78 °C erhitzt. Das Infusionsverfahren findet komplett in der Maischepfanne statt.

##### Erreichbare Umweltvorteile

Geringere Luftverschmutzung z. B. durch Geruch und weniger Energieverbrauch als beim Dekoktionsverfahren (siehe Abschnitt 4.7.9.6.3).

##### Betriebsdaten

Beim Infusionsverfahren muss die Maische nicht in Teilen erhitzt werden, wie dies beim Dekoktionsverfahren der Fall ist. Dadurch können Energieeinsparungen zwischen 20 und 50% erreicht werden. Tabelle 4.121 zeigt den Energieverbrauch im Sudhaus einer großen Brauerei in Deutschland, in der beim Maischen das Infusionsverfahren angewandt wird.

| Energieverbraucher         | Elektrische Energie |                     | Wärmeenergie                 |                     |                             |                    |
|----------------------------|---------------------|---------------------|------------------------------|---------------------|-----------------------------|--------------------|
|                            | Gesamt (kWh)        | Spezifisch (kWh/hl) | Gesamt (10 <sup>6</sup> kWh) | Spezifisch (kWh/hl) | Gesamt (10 <sup>6</sup> MJ) | Spezifisch (MJ/hl) |
| Würzherstellung im Sudhaus | 675.500             | 0,84                | 8,2                          | 10,2                | 29,52                       | 36,6               |
| Gesamtverbrauch            | 6.520.730           | 8,1                 | 22,82                        | 28,3                | 82,152                      | 101,9              |

Tabelle 4.121: Energieverbrauch im Sudhaus einer großen Brauerei, in der beim Maischen das Infusionsverfahren angewandt wird.

Es wird berichtet, dass das Infusionsverfahren zusätzlich noch geringere Geruchsemissionswerte aufweist als das Dekoktionsverfahren.

### Anwendbarkeit

Das Infusionsverfahren kann beim Maischen in der Herstellung vollmalziger Biere angewandt werden. Traditionell ist für das Infusionsverfahren ein qualitativ hochwertiges Malz erforderlich, doch die zur Verfügung stehenden Malzqualitäten erlauben die Herstellung vieler Bierarten mit dem Infusionsverfahren.

### Wirtschaftlichkeit

Keine zusätzlichen Kosten im Vergleich zum Dekoktionsverfahren.

### Anlass für die Umsetzung

Das Infusionsverfahren beim Maischen wird in erster Linie wegen des geringeren Energieverbrauchs eingesetzt, denn es erfordert weniger Gerätschaften als das Dekoktionsverfahren und ist zudem noch einfacher zu automatisieren.

### Beispielanlage

Eine Großbrauerei in Deutschland.

### Referenzliteratur

[65, Germany, 2002, 136, CBMC - The Brewers of Europe, 2002, 216, CBMC - The Brewers of Europe, 2004]

## **4.7.9.6.3 Maischen nach dem Dekoktionsverfahren**

### Beschreibung

Geschrotetes Malz wird gemeinsam mit warmem Wasser in die Maischepfanne gegeben. Diese sogenannte Maische wird unter ständigem Rühren auf 78 °C erhitzt. Dann wird der dickere Teil der Maische abgetrennt und in einer Maischepfanne gekocht, d. h. auf 100 °C erhitzt.

### Medienübergreifende Effekte

Höhere Luftverschmutzung z. B. durch Geruch und höherer Energieverbrauch im Vergleich zum Infusionsverfahren (siehe Abschnitt 4.7.9.6.2).

### Betriebsdaten

Es wird berichtet, dass die Wärmeverluste bei diesem Verfahren höher sind als beim Infusionsverfahren, da Teilmaische gekocht wird. Außerdem weist das Dekoktionsverfahren angabegemäß höhere Geruchsemissionswerte auf als das Infusionsverfahren.

### Anwendbarkeit

Das Dekoktionsverfahren wird angewandt, wenn ungemälzte Rohware, z. B. Mais, eingesetzt wird.

### Referenzliteratur

[65, Germany, 2002, 136, CBMC - The Brewers of Europe, 2002, 216, CBMC - The Brewers of Europe, 2004]

## **4.7.9.6.4 Wiederverwendung des Heißwassers aus der Würzekühlung**

### Beschreibung

In Bezug auf Energieeinsparungen ist der Verbrauch an Heißwasser ein wichtiger Parameter. Heißwasser entsteht in der Regel in einem Wärmetauscher beim Abkühlen der Würze von 100 °C auf die Fermentationstemperatur, z. B. etwa 10 °C. Das heiße Wasser wird in isolierten Wassertanks gelagert und für verschiedene Prozesse genutzt, z. B. in der Produktion, für die Reinigung, zum Spülen der Braukessel oder zum Heizen von Räumen.

### Erreichbare Umweltvorteile

Geringerer Energieverbrauch. Weniger Wasserverbrauch und eine bessere Heißwasserbilanz des Vorgangs. Verringerte Geruchsemissionen.

### Betriebsdaten

Es wird berichtet, dass bei alleiniger Verwendung des Heißwassers für das Maischen zu viel Heißwasser anfällt und der Heißwassertank überläuft. Durch dieses Überlaufen können große Mengen an Wasser und Energie verlorengehen. Um das Heißwassersystem zu optimieren, kann eine Heißwasserbilanz für die gesamte Brauerei erstellt werden. Dabei sollte sorgfältig untersucht werden, wann, wo und wie viel Heißwasser verwendet wird. Die Untersuchungen sollten auch aufzeigen, ob es möglich ist, Heißwasser anstelle von mit Dampf erhitztem

Kaltwasser für Aufgaben wie CIP, Sterilisation und Flaschenreinigung zu nutzen. Wichtig ist weiterhin, dass der Heißwassertank die richtige Größe hat, damit im Sudhaus nach einer Wochenendpause nicht Heißwasser mittels Dampf erzeugt werden muss.

#### Anwendbarkeit

In allen Brauereien anwendbar.

#### Referenzliteratur

[136, CBMC - The Brewers of Europe, 2002, 216, CBMC - The Brewers of Europe, 2004]

#### 4.7.9.6.5 Wärmerückgewinnung aus der Würzekochung

##### Beschreibung

In einer Brauerei ist das Kochen der Würze das Einzelverfahren mit dem größten Wärmeverbrauch. Beim Kochen der Würze verdampfen in der Regel 6-10%. Der Brüden wird gewöhnlich in die Luft abgegeben. Damit wird Energie verschwendet, und es entstehen unangenehme Gerüche. Die Rückgewinnung der Wärme aus den Würzekesseln spart Energie und vermeidet Geruchsprobleme.

Die einfachste Möglichkeit der Wärmerückgewinnung aus dem Brüden ist die Erzeugung von Heißwasser für verschiedene Prozesse, z. B. zur Nutzung in der Produktion, für die Reinigung, zum Spülen der Braukessel oder zum Heizen von Räumen. Falls jedoch – wie vielfach üblich – Heißwasser auch bei der Kühlung der Würze erzeugt wird (siehe Abschnitt 4.7.9.6.4), kann es zu einem Überschuss an Heißwasser kommen, das dann in die Kläranlage abgeleitet wird. In diesem Fall wurden zwei Möglichkeiten zur Wärmerückgewinnung aus dem Brüden berichtet: Entweder werden die Brüden zum Kochen der Würze genutzt oder die Wärme aus den Brüden wird eingesetzt, um die Würze vor dem Kochen vorzuwärmen.

##### Erreichbare Umweltvorteile

Erheblich geringerer Energieverbrauch. Weniger Wasserverbrauch und eine bessere Heißwasserbilanz des Vorgangs. Verringerte Geruchsemissionen.

##### Betriebsdaten

Dampf, der mittels Brüdenverdichtung erzeugt wird, wird üblicherweise genutzt, um die Würze in einem speziellen Wärmetauscher zu kochen. Es wird berichtet, dass die Wärme aus dem kondensierten Dampf, der eine Temperatur von etwa 100 °C hat, rückgewonnen werden kann, indem damit das Heißwasser erzeugt wird, das zum Kochen der Würze nötig ist. Das Verfahren wird in Abbildung 4.82 dargestellt.

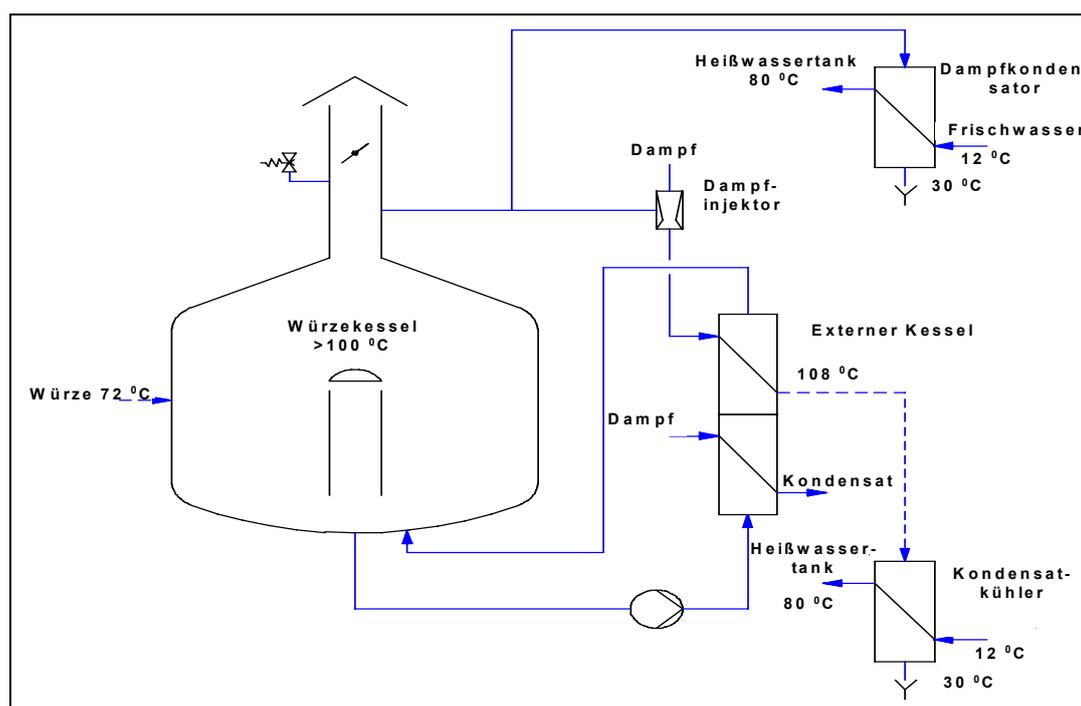


Abbildung 4.82: Wärmerückgewinnung aus einem mit Dampf erhitzten Würzekessel zur Erzeugung von Heißwasser

Es wird auch berichtet, dass die Wärme genutzt werden kann, um 98 °C heißes Wasser zu erzeugen, das die Würze vor dem Kochen vorwärmt. Die Würze kann durch die aus dem Dampfkondensat rückgewonnene Wärme von 72 °C auf etwa 90 °C erhitzt werden. Das erfordert die Installation eines Energiespeichers. Die im Dampfkondensat enthaltene Wärme kann ebenfalls, sofern erforderlich, zur Erzeugung von Heißwasser dienen. Das Verfahren ist in Abbildung 4.83 dargestellt.

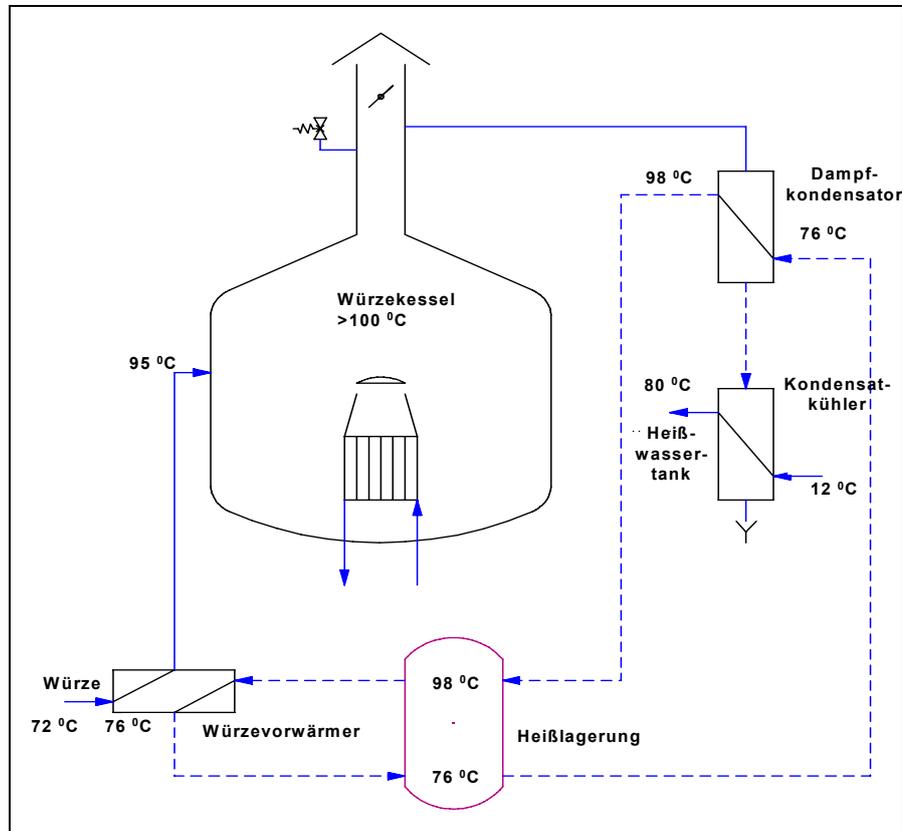


Abbildung 4.83: Wärmerückgewinnung aus der Erwärmung der Würze zum Vorheizen der Würze vor dem Kochen

Anwendbarkeit

Anwendbar in neuen Brauereien und in bestehenden Brauereien, wenn die Anlage einen hohen und ineffizienten Energieverbrauch hat. In diesen Fällen wird eine Wärmerückgewinnung nur dann in Betracht gezogen, wenn vorher andere erhebliche Reduzierungen im Energieverbrauch erfolgt sind, z. B. auf einen Wert von 41,66-55,55 kWh/hl (150-200 MJ/hl).

Wirtschaftlichkeit

Hohe Kapitalkosten.

Anlässe für die Umsetzung

Kosteneinsparungen, z. B. weniger Kosten für Energie- und Wasserverbrauch.

Referenzliteratur

[59, Danbrew Ltd., 1996, 65, Germany, 2002, 136, CBMC - The Brewers of Europe, 2002, 216, CBMC - The Brewers of Europe, 2004]

**4.7.9.6 Prozessoptimierung in einer kleinen Brauerei – eine Fallstudie**

Beschreibung

Eine kleine Brauerei in Großbritannien stellt hauptsächlich Ales und Lagerbier in Fässern auf einem alten, traditionellen Werksgelände her. Als erkannt wurde, dass die Bierverluste und die Abwasserkosten über dem Durchschnitt des Sektors lagen, wurden Messeinrichtungen für den Wasserverbrauch und die Abwasserabgabe in den wichtigsten Prozessbereichen eingebaut (siehe Abschnitt 4.1.8.7); zum Beispiel wurden schwimmer-

gesteuerte Auffüllventile in Reinigungsmitteltanks installiert und defekte Ventile ersetzt. Außerdem wurden bessere Verfahren zur Wiederverwendung von Heißwasser aus der Würzekühlung eingeführt (siehe Abschnitt 4.7.9.6.4) und hocheffiziente Düsen für die Reinigung der Fässer installiert und die Reinigungsverfahren optimiert.

#### Erreichbare Umweltvorteile

Effizientere Wasser- und Energienutzung und Minimierung der Abwassermenge.

#### Betriebsdaten

Damit erzielte das Unternehmen eine Verringerung des jährlichen Wasserverbrauchs um 73.000 m<sup>3</sup> (40%).

#### Wirtschaftlichkeit

Geringe Investitionsmaßnahmen. Es wurden jährliche Kosteneinsparungen von fast 160.000 Euro erzielt, wobei fast 130.000 Euro sich in weniger als drei Monaten amortisiert hatten.

#### Referenzliteratur

[1, CIAA, 2002]

### 4.7.9.7 Destillation

#### 4.7.9.7.1 Rückgewinnung von festen und gelösten Stoffen aus der Destillation (distiller's dried grains with solubles, DDGS)

#### Beschreibung

Aus Mais kann Alkohol gewonnen werden. Der Mais wird gemahlen und dann mit Wasser vermischt. Mit Hilfe von Enzymen werden in einem zweistufigen Verfahren Zucker produziert. Diese Zucker werden dann zu Alkohol fermentiert, und danach wird der Alkohol mittels Destillation vom Wasser getrennt. Die Schlempe wird über Dekanter in Feststoff und Dünnschlempe getrennt, die Dünnschlempe wird dann zu einem Sirup eingedampft. Der Sirup und die vorab abgetrennten Feststoffe werden wieder gemischt und thermisch auf einen Feststoffgehalt von 90% getrocknet. Dieses Produkt, das als Tierfutter verwendet werden kann, nennt man Distiller's Dried Grains with Solubles (DDGS). Es enthält Proteine, Vitamine und Mineralstoffe.

#### Erreichbare Umweltvorteile

Herstellung von Tierfutter.

#### Medienübergreifende Effekte

Staub kann entstehen, und Energie wird verbraucht.

#### Betriebsdaten

Vor der Trocknung hat die Mischung aus Sirup und Feststoffen eine Temperatur von etwa 70 °C, die auf 110 °C erhöht wird. Das Produkt hat eine Temperatur von etwa 30 °C. Der Verdampfer wird mit Natronlauge (NaOH) gereinigt, die auch dazu verwendet wird, den pH-Wert während der alkoholischen Fermentation zu steuern. Einige Verbrauchswerte sind in Tabelle 4.122 angegeben.

| Parameter           | Verbrauch pro t hergestellter DDGS |
|---------------------|------------------------------------|
| Dampf               | 4,5 t                              |
| Elektrische Energie | 300 kWh                            |
| NaOH                | 15 kg                              |
| Wasser              | 0,1 m <sup>3</sup>                 |

**Tabelle 4.122: Verbrauchswerte für die Trocknung von DDGS**

#### Anwendbarkeit

Anwendbar bei der Herstellung von Alkohol aus Getreide.

#### Wirtschaftlichkeit

Das Produkt kann fast zum gleichen Preis wie Mais verkauft werden.

### Anlässe für die Umsetzung

Ohne diese Rückgewinnung müssen die Schlempereste entsorgt werden.

### Referenzliteratur

[179, Gergely, 2003]

#### **4.7.9.7.2 Konzentration der Schlempe aus der Melassedestillation**

##### Beschreibung

Durch Fermentation der Melasse aus der Zuckerrübenverarbeitung und anschließende Destillation/Rektifikation kann Alkohol hergestellt werden. Die Melasseschlempe ist stark verunreinigt, z. B. BSB<sub>5</sub> von 18.000-22.000 mg/l, und enthält Verbindungen, die biologisch schwer abbaubar sind. Die Einleitung von Melasseschlempe in das Abwasser würde den Betrieb jeder Kläranlage behindern. Daher muss Melasseschlempe behandelt werden.

Die Melasseschlempe kann in einem mehrstufigen Vakuumverdampfer aufkonzentriert und verarbeitet werden. Die entstehenden Produkte sind Vinasse (Dickschlempe) und kaliumsulfathaltige Salze. Mit dem Vakuumverdampfer erzielt man einen Feststoffgehalt von 70%. In einer anschließende Zentrifugation werden Vinasse und Salze getrennt. Vinasse ist ein dunkelbrauner Sirup, der alle anorganischen Stoffe aus der Würze und der Melasseschlempe enthält und als Tierfutter Verwendung findet. Die Salze werden als Kaliumdünger verwendet.

Das Brüdenkondensat aus der Konzentration der Melasseschlempe wird vor der Einleitung in die Kläranlage über einen Kationenaustauscher geführt, um das Ammonium zu entfernen. Bei diesem Verfahren entsteht Ammoniumsulfat, das zum Verdampfer zurückgeführt wird, damit das Kalium in der Melasseschlempe in Kaliumsulfat umgewandelt werden kann.

##### Erreichbare Umweltvorteile

Geringere Verschmutzung des Abwassers. Weniger Abfall, z. B. werden die Vinasse als Tierfutter und die Salze als Kaliumdünger genutzt.

##### Betriebsdaten

In Tabelle 4.123 sind Verbrauchs- und Emissionswerte einer deutschen Beispielanlage zur Destillation von Melasse aus den Jahren 1999/2000 angegeben.

| Parameter   | Einheit  | Menge         |
|---|--|---------------|
| Wasserverbrauch   | m <sup>3</sup> /t Vinasse  | 1,5           |
| Energieverbrauch  |  |               |
| Dampf   | t  | 5.305         |
| Elektrische Energie   | MWh  | 993,2         |
| Zusätzlich in der Saison<br>1999/2000 eingebrachte<br>Betriebs- und Hilfsstoffe |  |               |
| Natronlauge   | kg   | 1.402         |
| Entschäumer   | kg   | 3.419         |
| Ammoniumsulfat  | kg   | 139.300       |
| Regeneriersalz  | kg   | 600           |
| Produkte  |  |               |
| Vinasse   | t  | 3539          |
| Salze   | t  | 754           |
| Abwasser  |  |               |
| Volumen   | m <sup>3</sup> /h  | 10 – 12       |
| CSB-Gehalt  | mg/l   | 2.500 – 4.000 |
| BSB <sub>5</sub> -Gehalt  | mg/l   | 1.000 – 2.000 |
| NH <sub>4</sub> -N-Gehalt   | mg/l   | 600 – 800     |
| Gesamt Phosphat   | mg/l   | 0,5 – 1,0     |
| Abluft und Staubemissionen  | Unerheblich. Die Abluft wird über einen Torfbiofilter gereinigt. |               |
| Lärmemissionen  | 51 dB(A) (komplette Anlage bei geschlossenen Türen)              |               |

**Tabelle 4.123: Verbrauchs- und Emissionswerte der Verdampfungseinrichtung für Melasseschlempe in einer deutschen Melessedestillerie**

#### Anwendbarkeit

Anwendbar in Melessedestillieren.

#### Anlässe für die Umsetzung

Verbesserung des Betriebs der Kläranlage. Herstellung von Nebenprodukten.

#### Beispielanlagen

Mindestens eine Melessedestillerie in Deutschland.

#### Referenzliteratur

[65, Germany, 2002]

### 4.7.9.8 Wein

#### 4.7.9.8.1 Wiederverwendung der Reinigungslösung aus den Kaltstabilisationstanks

##### Beschreibung

Die Kaltstabilisation beinhaltet das rasche Abkühlen des Weines fast auf Gefriertemperatur, um Calcium- und Kaliumtartrat auszufällen. Diese Salze können in Flaschenweinen vorkommen, sind aber unerwünscht. Die Weinsteinkristalle fallen während des Ausbaus/Abstichs und der Stabilisation aus.

Nachdem das Gefäß entleert wurde, wird eine 10%ige Natronlauge zugesetzt, um die Weinsteinkristalle zu entfernen. Diese Reinigungslauge kann wiederverwendet werden, wenn der Weinstein aus der Lösung rückgewonnen wird. Alternativ kann der Weinstein auch mit Hilfe der Elektrodialyse aus dem Wein entfernt werden, wodurch die Verwendung einer alkalischen Lösung vermieden wird. Dadurch erreicht man geringere Energiekosten im Vergleich zum Kühlen des Weins.

##### Erreichbare Umweltvorteile

Weniger Verbrauch an Wasser und alkalischer Reinigungslösung und geringere Verschmutzung des Abwassers.

### Betriebsdaten

Das Verfahren zur Rückgewinnung des Weinsteines wurde nicht beschrieben, es wird jedoch berichtet, dass die in die Kläranlage eingeleitete Lösung unerwünschte Schwankungen des pH-Wertes verursacht, wenn diese Rückgewinnung nicht stattfindet. Die als Nebenprodukt entstehende Weinsäure kann in der pharmazeutischen Industrie und in der Baustoffindustrie verwendet werden.

### Anwendbarkeit

Anwendbar in allen Anlagen zur Weinherstellung, die Ausbau/Abstich und Stabilisation durchführen.

### Beispielanlagen

Wird in der Weinherstellung eingesetzt.

### Referenzliteratur

[134, AWARENET, 2002]

#### **4.7.9.8.2 Allmähliche Ableitung der Reinigungslösung aus den Kaltstabilisationstanks in die Kläranlage**

### Beschreibung

Während des Ausbaus/Abstichs und der Kaltstabilisation fallen Calcium- und Kaliumtartrate als Kristalle aus und werden dann mit Hilfe einer alkalischen Reinigungslösung entfernt. Um unerwünschte Schwankungen des pH-Werts zu vermeiden, wird die benutzte Reinigungslösung schrittweise in die Kläranlage geleitet.

### Betriebsdaten

Wenn die alkalische Reinigungslösung auf einmal in die Kläranlage geleitet wird, entstehen im Abwasser unerwünschte pH-Wert-Schwankungen, die den Betrieb der Kläranlage unterbrechen können.

### Anwendbarkeit

Wenn die alkalische Reinigungslösung ihre Wirksamkeit verloren hat, selbst nach Rückgewinnung des Weinsteines, und wenn die Möglichkeit der Selbstneutralisation nicht gegeben ist.

### Anlass für die Umsetzung

Weniger Unterbrechungen des Betriebs der Kläranlage.

### Beispielanlagen

Wird in der Weinherstellung eingesetzt.

### Referenzliteratur

[134, AWARENET, 2002]

## 5 BESTE VERFÜGBARE TECHNIKEN

Zum besseren Verständnis dieses Kapitels und seiner Inhalte wird noch einmal auf das Vorwort zu diesem Dokument und insbesondere auf Abschnitt 5 des Vorwortes verwiesen: "Anleitung zum Verständnis und zur Benutzung des vorliegenden Dokuments" Die in diesem Kapitel beschriebenen Techniken und die damit zusammenhängenden Verbrauchs- und/oder Emissionswerte bzw. Wertebereiche wurden in einem aus folgenden Schritten bestehenden iterativen Verfahren ermittelt:

- Identifizierung der wichtigsten umweltrelevanten Faktoren für diesen Bereich. Dazu gehören der Wasser- und Energieverbrauch, das Abwasseraufkommen und in geringerem Umfang die Entstehung fester Abfälle und die Geruchsbildung
- Untersuchung der Techniken, die für diese wichtigen Faktoren am relevantesten sind
- Identifizierung der besten Umweltleistungen auf der Grundlage der in der europäischen Union und weltweit verfügbaren Daten
- Untersuchung der Bedingungen, unter denen diese Leistungen erreicht werden, z. B. Kosten, medienübergreifende Effekte, wichtigste Anlässe für die Umsetzung dieser Techniken
- Auswahl der besten verfügbaren Techniken (BVT) und der damit zusammenhängenden Verbrauchs- und/oder Emissionswerte für diesen Bereich im Allgemeinen, und zwar in Übereinstimmung mit Artikel 2 Absatz 11 und Anhang IV der Richtlinie.

Für jeden dieser Schritte und für die Art, wie die Informationen in dem vorliegenden Dokument präsentiert werden, haben das Fachurteil des europäischen IVU-Büros und der zuständigen Technischen Arbeitsgruppe (TAG) eine wichtige Rolle gespielt.

Auf der Grundlage dieser Einschätzungen werden in diesem Kapitel Techniken und, soweit möglich, Verbrauchs- und Emissionswerte im Zusammenhang mit dem Einsatz der BVT präsentiert, die für diesen Bereich als Ganzes als angemessen angesehen werden, und die in vielen Fällen die derzeitige Leistung einiger Anlagen innerhalb des Bereichs widerspiegeln. Werden Verbrauchs- oder Emissionswerte "im Zusammenhang mit den besten verfügbaren Techniken" angegeben, dann ist dies so zu verstehen, dass diese Werte die Umweltleistung darstellen, die unter Berücksichtigung der Ausgewogenheit von Kosten und Vorteilen entsprechend der Definition der BVT als Ergebnis des Einsatzes der beschriebenen Techniken in diesem Bereich angenommen werden kann. Allerdings sind diese Verbrauchs- oder Emissionswerte keine Grenzwerte und sollten auch nicht als solche aufgefasst werden. In einigen Fällen mag es technisch möglich sein, bessere Verbrauchs- oder Emissionswerte zu erzielen, aber sie werden wegen der damit verbundenen Kosten oder medienübergreifenden Überlegungen für die BVT des gesamten Bereichs als nicht angemessen angesehen. Allerdings könnten solche Werte in speziellen Fällen, in denen besondere Beweggründe vorliegen, als gerechtfertigt angesehen werden.

Die Verbrauchs- oder Emissionswerte im Zusammenhang mit dem Einsatz der BVT müssen gemeinsam mit den angegebenen Referenzbedingungen (z. B. Durchschnittsdauer) betrachtet werden.

Das oben beschriebene Konzept der "Werte im Zusammenhang mit BVT" muss von dem ebenfalls in diesem Dokument verwendeten Begriff "erreichbare Werte" unterschieden werden. Wird ein Wert als mit Hilfe einer speziellen Technik oder einer Kombination von Techniken "erreichbar" beschrieben, so ist dies so zu verstehen, dass das Erreichen dieses Wertes im Laufe einer längeren Zeitspanne in einer gut gewarteten und geführten Anlage oder mit einem Verfahren, in dem diese Techniken eingesetzt werden, erwartet werden kann.

Angaben zu den Kosten wurden, sofern verfügbar, bei der Beschreibung der Techniken im vorherigen Kapitel gemacht. Es sind grobe Anhaltspunkte für die Größenordnung, in der sich die entsprechenden Kosten bewegen. Die tatsächlichen Kosten für den Einsatz einer Technik hängen stark von der jeweiligen Situation ab, z. B. in Bezug auf Steuern, Gebühren und die technischen Eigenschaften der entsprechenden Anlage. Es ist nicht möglich, diese werksspezifischen Faktoren in diesem Dokument umfassend zu beurteilen. Falls keine Informationen zu den Kosten vorlagen, wurden Schlussfolgerungen zur wirtschaftlichen Vertretbarkeit der Techniken aus Beobachtungen bereits bestehender Anlagen gezogen.

Die allgemeinen BVT in diesem Kapitel sind als Referenzangaben für die Beurteilung der derzeitigen Leistung einer bestehenden Anlage oder eines Antrags für eine neue Anlage gedacht. Sie helfen daher bei der Bestimmung der jeweiligen BVT-gestützten Auflagen für die Anlage oder bei der Festlegung allgemein verbindlicher Vorschriften gemäß Artikel 9 Absatz 8. Neue Anlagen sollen so entworfen werden, dass ihre

Leistung den allgemeinen, hier angegebenen BVT-Werten entspricht oder diese sogar übertrifft. Ebenso wird berücksichtigt, dass sich bestehende Anlagen je nach technischer oder wirtschaftlicher Eignung der Techniken im betreffenden Fall den allgemeinen BVT-Werten nähern oder diese übertreffen könnten.

Die BVT-Referenzdokumente enthalten keine gesetzlich bindenden Normen, sondern sind bezüglich der beim Einsatz spezieller Techniken erreichbaren Verbrauchs- und Emissionswerte als Orientierungshilfe für Industrie, Mitgliedsstaaten und Öffentlichkeit gedacht. Die jeweiligen Grenzwerte müssen für jeden einzelnen Fall unter Berücksichtigung der Ziele der IVU-Richtlinie und lokaler Gegebenheiten festgelegt werden.

Maßnahmen zur Vermeidung und Kontrolle der Verbrauchs- und Emissionswerte hängen sehr stark davon ab, dass jeder Prozess technisch und betriebstechnisch auf der Ebene des jeweiligen Arbeitsbereichs geplant wird. Deshalb wurden die BVT so detailliert beschrieben. Falls Verbrauch oder Emissionen nicht vermieden werden können, soll mit Hilfe der BVT ihre Umweltwirkung durch den Einsatz von technischen und betriebstechnischen Verfahren verringert werden.

Es gibt zum Beispiel in vielen Betriebseinheiten Möglichkeiten, unnötigen Wasserverbrauch zu vermeiden, was sich manchmal auch in Energieeinsparungen niederschlägt. Zum Beispiel verringert der Verbrauch an Heißwasser nicht nur den Wasserverbrauch, sondern es wird auch weniger Energie zur Wassererhitzung benötigt. Die Wasserverschmutzung lässt sich dadurch verringern, dass unnötiger Kontakt von Wasser mit Lebensmitteln vermieden und die Trockenreinigung angewandt wird.

Durch eine rasche Verarbeitung der Lebensmittel können die Abfallmengen und Geruchsprobleme, die mit der Zersetzung im Laufe der Zeit auftreten würden, während der Lagerung und Verarbeitung verhindert oder minimiert werden.

Die BVT wurden unter Berücksichtigung der Anforderungen an Anlagen für die Nahrungsmittelproduktion ausgewählt, um eine Übereinstimmung mit anderen Rechtsvorschriften, etwa in Bezug auf öffentliche Gesundheit, Lebensmittel- und Futtermittelsicherheit sowie Gesundheit und Sicherheit am Arbeitsplatz zu erreichen.

Die Nahrungsmittelproduktion (im Englischen: Food, Drink and Milk [FDM] sector) ist ein vielschichtiger, heterogener und fragmentierter Bereich, der sich aus einer großen Vielfalt verschiedener Nahrungsmittel- und Getränke-segmente, z. B. Fleisch, Zucker und Kaffee, zusammensetzt. In der gesamten Industrie kommen hunderte von Verfahren zum Einsatz. Die Umweltaspekte ebenso wie Art und Menge der entstehenden Abfälle schwanken je nach Sektor, Verfahren und eingesetzten Rohstoffen. Es ist daher im Rahmen dieses Dokuments nicht möglich, spezielle BVT für jedes spezielle, in der Nahrungsmittelproduktion eingesetzte Verfahren festzulegen.

Im Folgenden wird in diesem Kapitel über die BVT für Anlagen in der Nahrungsmittelindustrie berichtet. Zunächst werden allgemeine BVT vorgestellt, die sämtliche Anlagen betreffen. Neben den allgemeinen gibt es noch weitere BVT, die nur auf einzelne Prozesse oder Arbeitsgänge in der Nahrungsmittelproduktion anzuwenden sind, in denen diese Prozesse oder Arbeitsgänge auch zur Anwendung kommen. Es werden auch BVT erwähnt, die nur für einzelne Industriezweige anzuwenden sind, d. h. für solche, die Fleisch, Fisch oder Meeresfrüchte, Obst und Gemüse, pflanzliche Öle und Fette, Milch, Stärke, Zucker, Kaffee und Getränke verarbeiten. Für die Bereiche, für die keine zusätzlichen BVT erwähnt werden, z. B. für Mühlenerzeugnisse, die Herstellung von Trockennudeln und Tierfutter, die Herstellung von Brot, Süßwaren und Hefe, für das Mälzen, Destillieren, die Herstellung von Apfelwein, alkoholfreien Erfrischungsgetränken und Zitronensäure, gelten die allgemeinen BVT.

Zur besseren Übersicht wird in Abbildung 5.1 dargestellt, in welcher Form die BVT-Schlussfolgerungen abgehandelt werden. In dieser Abbildung sind die BVT-Schlussfolgerungen in zwei Gliederungsebenen dargestellt. Die erste Gliederungsebene gibt die BVT-Bereiche für alle Anlagen der Nahrungsmittelindustrie an, und die zweite Ebene enthält die Bereiche, in denen zusätzliche BVT für einzelne Branchen aufgeführt sind.

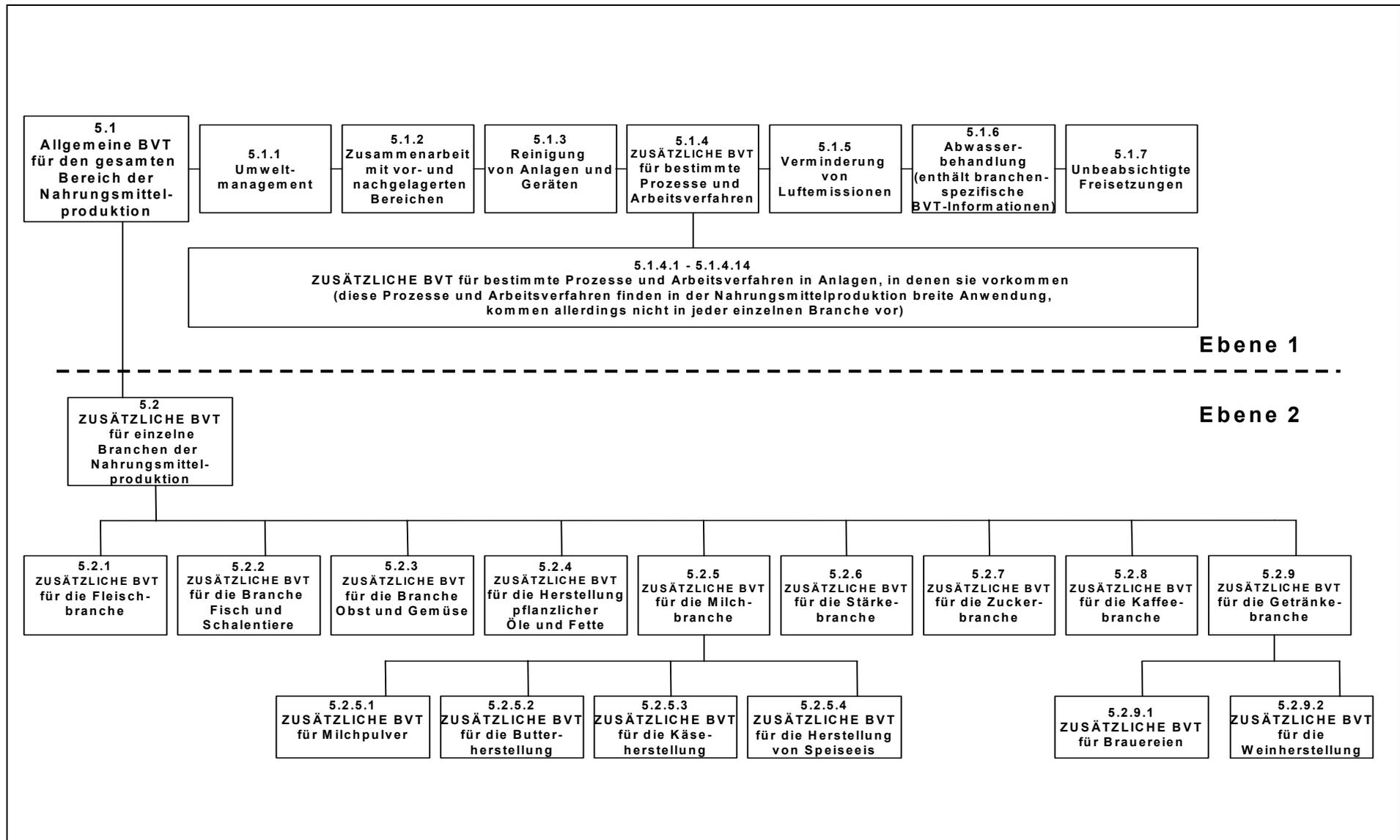


Abbildung 5.1: Darstellung der BVT-Schlussfolgerungen für Anlagen der Nahrungsmittelindustrie

Die Durchnummerierung der BVT in diesem Kapitel erleichtert das Lesen und die Bezugnahme in Diskussionen. Die Nummerierung stellt keine Hierarchie dar.

### 5.1 Allgemeine BVT für den gesamten Bereich der Nahrungsmittelproduktion

Eine Reihe von Techniken wurde als allgemeine BVT festgelegt, die für alle oder die Mehrzahl der industriellen Abläufe in der Nahrungsmittelindustrie gelten und in diesem Abschnitt beschrieben werden. Es handelt sich um allgemeine Techniken, die üblicherweise in der gesamten Nahrungsmittelindustrie verwendet werden, unabhängig davon, welche Prozesse angewandt oder Produkte hergestellt werden.

**Für alle Anlagen der Nahrungsmittelindustrie umfassen die BVT die Erfüllung der folgenden Punkte:**

- 1 Gewährleistung, z. B. durch Schulung, dass sich die Mitarbeiter der umweltrelevanten Aspekte der Abläufe im Unternehmen und ihrer persönlichen Verantwortung bewusst sind (siehe Abschnitt 4.1.2)
- 2 Entwurf/Auswahl von Geräten und Maschinen, die die Verbrauchs- und Emissionswerte optimieren und eine korrekte Arbeitsweise und Wartung erleichtern (siehe Abschnitt 4.1.3.1), z. B. Optimierung des Leitungssystems, um Produktverluste zu minimieren, und Installation von Gefälleleitungen, um ein automatisches Leerlaufen zu fördern.
- 3 Einschränkung der Geräuschemissionen beim Verursacher durch Entwicklung, Auswahl, Betrieb und Wartung von Geräten, einschließlich Fahrzeugen, um das Auftreten zu verhindern oder zu verringern (siehe Abschnitte 4.1.2, 4.1.3.1, 4.1.3.2, 4.1.3.3, 4.1.3.4 und 4.1.5) und, falls eine weitere Eindämmung des Geräuschpegels erforderlich ist, die Einhausung der lärmerzeugenden Einrichtung (siehe Abschnitt 4.1.3.5).
- 4 Durchführung regelmäßiger Wartungsprogramme (siehe Abschnitt 4.1.5).
- 5 Anwendung und Beibehaltung einer Methodik zur Verhinderung und Reduzierung des Wasser- und Energieverbrauchs und des Abfallanfalls (siehe Abschnitt 4.1.6); dazu gehören:
  - 5.1 Engagement des Managements sowie Organisation und Planung durch das Management (siehe Abschnitte 4.1.6.1)
  - 5.2 Analyse der Produktionsprozesse, einschließlich individueller Verfahrensschritte zur Identifizierung von Bereichen hohen Wasser- und Energieverbrauchs und hohen Abfallanfalls, um Möglichkeiten der Reduzierung zu finden (siehe Abschnitte 4.1.6.2, 4.1.6.2.1, 4.1.6.2.2 und 4.1.6.2.3), unter Berücksichtigung der für jede Anwendung geforderten Wasserqualität sowie von Hygiene und Lebensmittelsicherheit
  - 5.3 Bewertung von Zielen, Vorgaben und Systemgrenzen (siehe Abschnitt 4.1.6.3)
  - 5.4 Identifizierung von Möglichkeiten, den Verbrauch von Wasser und Energie und das Abfallanfalls zu reduzieren (siehe Abschnitt 4.1.6.4), und zwar unter Verwendung eines systematischen Ansatzes wie der Pinch-Technologie (siehe Abschnitt 4.1.6.4.1)
  - 5.5 Durchführung einer Bewertung und einer Machbarkeitsstudie (siehe Abschnitt 4.1.6.5)
  - 5.6 Umsetzung eines Programms zur Reduzierung des Verbrauchs von Wasser und Energie sowie des Abfallanfalls (siehe Abschnitt 4.1.6.6) und
  - 5.7 Fortlaufende Überwachung des Verbrauchs von Wasser und Energie sowie des Abfallanfalls und der Wirksamkeit der Kontrollmaßnahmen (siehe Abschnitt 4.1.6.7); dies sowohl durch Messungen als auch durch Sichtprüfungen geschehen
- 6 Umsetzung eines Systems zur Überwachung und Überprüfung der Verbrauchs- und Emissionswerte sowohl für die einzelnen Produktionsverfahren wie auch für die gesamte Anlage, das die Optimierung der aktuellen Leistung ermöglicht. Zu den zu überwachenden Parametern gehören zum Beispiel: Energieverbrauch, Wasserverbrauch, Abwasseranfall, Emissionen in die Luft und ins Wasser, Abfallanfall, Produkt- und Nebenproduktausbeute, Verbrauch gefährlicher Stoffe und die Häufigkeit und Schwere unbeabsichtigter Freisetzungen und Auslaufen von Stoffen. Um die wichtigen Bereiche und die Möglichkeiten der Verbesserung der Umweltleistung zu identifizieren, sind gute Kenntnisse der im Verfahren eingesetzten Stoffe und erzeugten Produkte erforderlich. Zu einem guten Überwachungssystem gehören die Aufzeichnung der Betriebsbedingungen, der Probennahmen und Analyseverfahren sowie die Sicherstellung, dass die Messgeräte kalibriert sind. Weitere Informationen sind im "Referenzdokument über allgemeine Überwachungsgrundsätze" [96, EC, 2003] enthalten.

- 7 Führen einer genauen Inventarliste der eingesetzten und erzeugten Stoffe für alle Stufen des Verfahrens von der Anlieferung der Rohwaren bis zum Versand der Produkte und den Endbehandlungsverfahren (siehe Abschnitt 4.1.6.2)
- 8 Einsatz der Produktionsplanung zur Minimierung des Abfallanfalls und der Häufigkeit der Reinigungen (siehe Abschnitt 4.1.7.1).
- 9 Trockener Transport der festen Rohstoffe, Produkte, Koprodukte, Nebenprodukte und Abfälle (siehe Abschnitt 4.1.7.4) einschließlich der Vermeidung des Gebrauchs von Schwemmrinnen, außer wenn dabei ein Waschvorgang mit wiederverwendetem Wasser erfolgt und die Nutzung von Schwemmrinnen notwendig ist, um Schäden am zu transportierenden Material zu vermeiden
- 10 Minimierung der Lagerzeit verderblicher Produkte (siehe Abschnitt 4.1.7.3)
- 11 Trennung der anfallenden Stoffe zur Optimierung von Verwendung, Wiederverwendung, (Rückführung im Prozess) Wiederverwertung und Entsorgung (und Reduzierung der Abwasserkontamination) (siehe Abschnitte 4.1.7.6, 4.1.6, 4.1.7.7, 4.7.1.1, 4.7.2.1, 4.7.5.1 und 4.7.9.1)
- 12 Verhinderung des Herunterfallens von Material auf den Boden, z. B. durch entsprechend genau positionierte Spritzschutzvorrichtungen, Siebe, Klappen, Auffangschalen und Wannen (siehe Abschnitt 4.1.7.6)
- 13 Optimierung der Trennung der Wasserströme (siehe Abschnitt 4.1.7.8) zur Optimierung von Wiederverwendung und Behandlung
- 14 Getrenntes Auffangen der Wasserströme, z. B. Kondensat und Kühlwasser, zur Optimierung der Wiederverwendung (siehe Abschnitt 4.1.7.8)
- 15 Vermeidung des Verbrauchs von mehr Energie als für Erhitzung bzw. Kühlung notwendig sind, damit das Produkt keinen Schaden nimmt (siehe Abschnitt 4.1.7.9)
- 16 Einsatz der Maßnahmen der guten handwerklichen Praxis (siehe Abschnitt 4.1.7.11)
- 17 Minimierung der Geräuschbelästigung durch Fahrzeuge (siehe Abschnitt 4.1.7.12)
- 18 Anwendung von Lager- und Handhabungsverfahren entsprechend dem „BREF Lagerung“ [95, EC, 2005]. Weitere Kontrollen können erforderlich sein, damit die erforderlichen Hygiene- und Lebensmittelsicherheitsstandards erreicht und gewahrt werden.
- 19 Optimierung der An- und Verwendung von Verfahrenskontrollen, um z. B. den Verbrauch von Wasser und Energie zu verhindern oder zu reduzieren und um das Abfallaufkommen zu minimieren (siehe Abschnitt 4.1.8) und zwar insbesondere durch
- 19.1 Steuerung der Temperatur durch entsprechende Messungen und Korrekturen, wenn Erhitzungsverfahren angewendet und/oder Materialien bei kritischen Temperaturen oder innerhalb eines kritischen Temperaturbereichs gelagert oder transportiert werden (siehe Abschnitt 4.1.8.1)
- 19.2 Steuerung der Strömung und/oder Füllstände durch entsprechende Druckmessungen (siehe Abschnitt 4.1.8.2) und/oder durch entsprechende Strömungsmessungen (siehe Abschnitt 4.1.8.4) und/oder durch entsprechende Füllstandsmessungen (siehe Abschnitt 4.1.8.3) mit Hilfe von Kontrolleinrichtungen wie z. B. Ventilen (siehe Abschnitt 4.1.8.7), wenn Materialien gepumpt werden oder fließen
- 19.3 Einsatz von Füllstandsüberprüfungs- und Füllstandsmessungssensoren, wenn Flüssigkeiten in Tanks oder Behältern gelagert oder zur Reaktion gebracht werden, entweder während des Betriebs oder bei Reinigungsvorgängen (siehe Abschnitt 4.1.8.3)
- 19.4 Verwendung analytischer Mess- und Kontrollverfahren zur Verringerung der Verschwendung von Materialien und Wasser und zur Verringerung des im Betrieb und bei der Reinigung entstehenden Abwasseranfalls insbesondere durch
- 19.4.1 Messung des pH-Wertes zur Regelung der zugesetzten Säure oder Lauge und Messung zur Überwachung der Abwasserströme zwecks Regelung von Mischung und Neutralisation vor einer Weiterbehandlung oder Entsorgung (siehe Abschnitt 4.1.8.5.1)
- 19.4.2 Messung der Leitfähigkeit zur Überwachung der Menge gelöster Salze vor der Wiederverwendung von Wasser und zum Nachweis von aktiven Reinigungsmitteln vor der Wiederverwendung der Reinigungslösung (siehe Abschnitt 4.1.8.5.2) und
- 19.4.3 Messung der Trübung von Flüssigkeiten, die aufgrund suspendierter Teilchen trüb oder undurchsichtig sind, zur Überwachung der Prozesswasserqualität und zur Optimierung sowohl der Rückgewinnung von Stoffen/Produkten aus dem Wasser als auch der Wiederverwendung von Reinigungswasser (siehe Abschnitt 4.1.8.5.3)
- 20 Einsatz automatischer Wasserstart- und -stoppeinrichtungen, damit Wasser nur dann fließt, wenn es auch benötigt wird (siehe Abschnitt 4.1.8.6)

- 21 Auswahl von Rohmaterial und Hilfsstoffen, mit denen die Entstehung fester Abfälle und gefährliche Emission in Luft und Wasser reduziert werden (siehe Abschnitte 4.1.9.1 und 4.1.9.2)
- 22 die Ausbringung auf landwirtschaftlichen Nutzflächen ist eine von der örtlichen Gesetzgebung abhängende Möglichkeit der Verwertung von Reststoffen aus der Nahrungsmittelproduktion, wie in Abschnitt 4.1.6 erörtert.

### 5.1.1 Umweltmanagement

Mehrere Umweltmanagementtechniken wurden als BVT festgelegt (siehe Abschnitt 4.1.1). Der Umfang (z. B. Detailebene) und die Art des UMS (z. B. genormt oder nicht genormt) hängen im Allgemeinen von der Art, Dimension und Komplexität der Anlage und der Bandbreite ihrer möglichen Umweltauswirkungen ab.

BVT heißt, es muss ein Umweltmanagementsystem (UMS) eingeführt und eingehalten werden, das – sofern unter den betreffenden Bedingungen angebracht – die folgenden Eigenschaften aufweist: (siehe Kapitel 3)

- Festlegung einer Umweltpolitik für die Anlage durch die Geschäftsführung (das Engagement der Geschäftsführung wird als Vorbedingung für eine erfolgreiche Anwendung anderer Eigenschaften des UMS betrachtet)
- Planung und Festlegung der notwendigen Verfahren
- Implementierung der Verfahren unter besonderer Berücksichtigung folgender Punkte:
  - Struktur und Verantwortlichkeit
  - Schulung, Bewusstsein und Kompetenz
  - Kommunikation
  - Einbeziehung der Mitarbeiter
  - Dokumentation
  - effiziente Prozesskontrolle
  - Wartungsprogramme
  - Vorbereitung auf Notfälle und Reaktionen im Notfall
  - Einhaltung der Umweltgesetze.
- Überprüfung der Leistung und das Ergreifen von Korrekturmaßnahmen unter besonderer Berücksichtigung folgender Punkte:
  - Überwachung und Messungen (siehe auch „Referenzdokument über allgemeine Überwachungsgrundsätze“)
  - Korrektur- und Vorbeugemaßnahmen
  - Aktualisierung von Unterlagen
  - unabhängige (sofern praktikabel) interne Prüfungen, um festzustellen, ob das Umweltmanagementsystem mit den geplanten Einrichtungen übereinstimmt und korrekt implementiert und gepflegt wird.
- Überprüfung durch die Unternehmensführung.

Drei weitere Eigenschaften, die die oben genannten schrittweise ergänzen können, werden als unterstützende Maßnahmen betrachtet. Allerdings ist ihr Fehlen im Allgemeinen nicht als mit den BVT unvereinbar zu betrachten. Diese drei zusätzlichen Schritte sind:

- Überprüfung und Validierung des Managementsystems und des Prüfungsverfahrens durch eine akkreditierte Zertifizierungsstelle oder einen externen UMS-Prüfer
- Erstellung und Publikation (und möglicherweise externe Validierung) eines regelmäßigen Umweltberichts, der alle wichtigen Umweltaspekte der Anlage beschreibt und einen jährlichen Vergleich mit den Umweltzielsetzungen und -einzelzielen, sowie gegebenenfalls mit den Sektor-Kennzahlen erlaubt.
- Implementierung und Einhaltung eines international anerkannten freiwilligen Systems, wie z. B. EMAS und EN ISO 14001:1996. Dieser freiwillige Schritt kann dem UMS höhere Glaubwürdigkeit verleihen. Insbesondere EMAS, das alle oben genannten Punkte einschließt, verleiht höhere Glaubwürdigkeit. Nicht genormte Systeme können jedoch prinzipiell genauso effektiv sein, sofern sie ordnungsgemäß geplant und umgesetzt werden.

Es ist auch wichtig, die folgenden möglichen Punkte des UMS zu berücksichtigen:

- Überlegungen zur Umweltwirkung einer schließlichen Stilllegung schon bei der Planung einer neuen Anlage

- Überlegungen zur Entwicklung saubererer Technologien

Falls möglich, sind regelmäßige Ermittlung von Branchenkennzahlen, einschließlich Energieeffizienz und Energieeinsparung, Auswahl der eingesetzten Produktionsmittel, Emissionen in die Luft, Einleitungen in das Abwasser, Wasserverbrauch und Abfallaufkommen durchzuführen.

### 5.1.2 Zusammenarbeit mit vor- und nachgelagerten Tätigkeiten

Die Tätigkeiten der mit der Lieferung von Rohware und anderen Zusatzstoffen an Anlagen zur Nahrungsmittelverarbeitung befassten Personen, beispielsweise Landwirte und Transportunternehmer, können sich auf die Umweltbedingungen in diesen Anlagen der Nahrungsmittelindustrie auswirken. Die Lieferanten von Rohware, teilweise oder vollständig verarbeiteten Produkten an Anlagen der Nahrungsmittelindustrie können die Umweltbedingungen dieser Betriebe beeinflussen. Gleichmaßen kann die Anlage der Nahrungsmittelindustrie die Umweltbedingungen nachgeschalteter Anlagen, die sie beliefert, beeinflussen, zum Beispiel andere Anlagen der Nahrungsmittelindustrie. Die Auswirkung auf die Umwelt kann von den Eigenschaften dieser Produkte, z. B. Frische, Separationsgrad der verschiedenen Materialien und ihre Spezifikation, beeinflusst werden.

Die BVT bestehen darin, die Zusammenarbeit mit vor- und nachgeschalteten Partnern anzustreben, um ein durchgehendes System der Umweltverantwortung zu schaffen, die Umweltverschmutzung zu minimieren und die Umwelt als Ganzes zu schützen (siehe z. B. Abschnitte 4.1.7.2, 4.1.7.3, 4.1.7.12, 4.1.9.1, 4.2.1.1, 4.2.4.1 und 4.7.2.3).

### 5.1.3 Reinigung von Anlagen und Geräten

Die Geräte und Anlagen der Nahrungsmittelindustrie müssen oft und mit hohem Standard gereinigt werden, denn aus Gründen der Nahrungsmittelsicherheit sind gegebene Hygienestandards einzuhalten.

**Für alle Anlagen der Nahrungsmittelindustrie umfassen die BVT die Erfüllung der folgenden Punkte:**

- 1 Schnellstmögliche Entfernung von Rohwarenresten nach der Verarbeitung und regelmäßige Säuberung der Lagerbereiche (siehe Abschnitt 4.3.10)
- 2 Auffangvorrichtungen oberhalb der Bodenabflüsse müssen vorhanden sein und verwendet werden. Um den Eintrag von Material in das Abwasser zu verhindern, ist ihre regelmäßige Inspektion und Reinigung sicherzustellen (siehe Abschnitt 4.3.1.1)
- 3 Optimierung des Einsatzes trockener Reinigungsverfahren (einschließlich Absaugverfahren) für Anlagen und Geräte auch nach Verschüttungen (siehe Abschnitte 4.3.1, 4.7.1.2, 4.7.2.2, 4.7.5.2 und 4.7.9.2) und vor der Nassreinigung, wenn eine Nassreinigung zur Einhaltung des entsprechenden Hygienegrades notwendig ist
- 4 Einweichen von Böden und offenen Geräten, um verhärteten oder angebrannten Schmutz vor der Nassreinigung zu lösen (siehe Abschnitt 4.3.2)
- 5 Bewirtschaftung und Minimierung der Verwendung von Wasser, Energie und Reinigungsmitteln (siehe Abschnitt 4.3.5)
- 6 Ausrüstung der für die manuelle Reinigung benutzten Schläuche mit Handauslösern (siehe Abschnitt 4.3.6)
- 7 Versorgung mit druckreguliertem Wasser unter Einsatz von Düsen (siehe Abschnitt 4.3.7.1)
- 8 Optimierung der Weiterverwendung des Warmwassers aus offenen Kühlkreisläufen, z. B. zum Reinigen (z. B. siehe Abschnitt 4.7.5.17)
- 9 Auswahl und Verwendung von Reinigungs- und Desinfektionsmitteln, die die Umwelt so wenig wie möglich schädigen (siehe Abschnitte 4.3.8, 4.3.8.1 und 4.3.8.2) und Durchführung einer wirksamen Hygienekontrolle
- 10 In geschlossenen Systemen Einsatz eines CIP-Verfahrens (cleaning-in-place) (siehe Abschnitt 4.3.9) und Sicherstellung, dass dieses optimal genutzt wird, z. B. durch Messung der Trübung (siehe Abschnitt 4.1.8.5.3), der Leitfähigkeit (siehe Abschnitt 4.1.8.5.2) oder des pH-Wertes (siehe Abschnitt 4.1.8.5.1) und automatische Dosierung der Chemikalien in den korrekten Mengen (siehe Abschnitt 4.3.9)
- 11 Einsatz von Einwegsystemen für kleine oder selten genutzte Anlagen oder für den Fall, dass die Reinigungslösung stark verschmutzt wird, z. B. bei UHT-Anlagen, Membrantrennanlagen und für die Vorreinigung von Verdampfern und Sprühtrocknern (siehe Abschnitt 4.3.9)

- 12 Durchführung einer Selbstneutralisation der alkalischen und säurehaltigen Abwasserströme in einem Neutralisationstank, wenn die pH-Wert-Schwankungen der Abwässer aus der CIP-Reinigung oder anderer Herkunft dies erlauben (siehe Abschnitt 4.5.2.4)
- 13 Minimierung der Verwendung von EDTA; Einsatz nur dort, wo es unbedingt erforderlich ist, und zwar nicht öfter und in nicht größerer Menge als nötig, z. B. durch Recycling der Reinigungslösungen<sup>39</sup> (siehe Abschnitte 4.3.8, 4.3.8.2, 4.3.8.2.2, 4.3.8.2.3 und 4.3.8.2.5).

**Bei der Auswahl chemischer Substanzen für die Desinfektion und Sterilisation von Geräten und Anlagen muss laut BVT:**

- 14 die Verwendung halogenierter oxidierender Biozide vermieden werden, mit Ausnahme dort, wo Alternativen nicht wirksam sind (siehe Abschnitte 4.3.8.1, 4.5.4.8, 4.5.4.8.1 und 4.5.4.8.2).

### **5.1.4 Zusätzliche BVT für Prozesse und Arbeitsverfahren, die in mehreren Branchen der Nahrungsmittelindustrie eingesetzt werden**

#### **5.1.4.1 Warenannahme/ -abfertigung**

**Während der Warenannahme und -abfertigung umfassen die BVT die Erfüllung des folgenden Punktes:**

- 1 Bei geparkten Fahrzeugen und während des Be- und Entladens sind der Motor und, falls vorhanden, die Kühleinheit des Fahrzeuges abzustellen und eine alternative Stromversorgung zu verwenden (siehe Abschnitt 4.2.1.1).

#### **5.1.4.2 Zentrifugation/Separation**

**Für alle Anlagen der Nahrungsmittelindustrie, in denen zentrifugiert wird, umfassen die BVT die Erfüllung des folgenden Punktes:**

- 1 Betrieb der Zentrifugen auf eine Art und Weise, dass der Austrag von Produkt ins Abwasser minimiert wird (siehe Abschnitt 4.2.3.1).

#### **5.1.4.3 Räucherei**

**Für alle Anlagen der Nahrungsmittelindustrie, in denen geräuchert wird, umfassen die BVT die Erfüllung des folgenden Punktes:**

- 1 Senkung der TOC-Emission in die Luft auf  $< 50 \text{ mg/Nm}^3$  (siehe z. B. Abschnitte 3.3.1.2.2 und 4.4.3.11.1).

#### **5.1.4.4 Frittieren**

**Für alle Anlagen der Nahrungsmittelindustrie, in denen frittiert wird, umfassen die BVT die Erfüllung des folgenden Punktes:**

- 1 Rezirkulation und Verbrennung der Abgase (siehe Abschnitt 4.2.7.1).

#### **5.1.4.5 Konservierung in Dosen, Flaschen und Gläsern**

**Für alle Anlagen der Nahrungsmittelindustrie, in denen Produkte in Dosen, Flaschen und Gläsern konserviert werden, umfassen die BVT die Erfüllung der folgenden Punkte:**

- 1 Einsatz automatischer Füllsysteme für Dosen, Flaschen und Gläser einschließlich eines geschlossenen Recycling-Kreislaufs für verschüttete Flüssigkeiten (siehe Abschnitt 4.2.8.2)

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<sup>39</sup> Anm. d. UBA-Bearb.: ... und Verwendung von Ersatzstoffen, die nicht auf EDTA-Basis aufgebaut sind

- 2 Verwendung von Reinigungstanks für Dosen, Flaschen und Gläser mit Rückgewinnung oben schwimmenden Öls, wenn Öl, in pflanzliche Öle eingelegte Lebensmittel oder ölige Lebensmittel konserviert werden (siehe Abschnitt 4.2.8.3).

#### 5.1.4.6 Verdampfung

**Für alle Anlagen der Nahrungsmittelindustrie, in denen eine Verdampfung erfolgt, umfassen die BVT die Erfüllung des folgenden Punktes:**

- 1 Bei der Konzentration von Flüssigkeiten Einsatz mehrstufiger Verdampfer (siehe Abschnitt 4.2.9.1) mit Optimierung der Brüdenverdichtung (siehe Abschnitt 4.2.9.2) gemäß der Verfügbarkeit von Wärme und Strom in der Anlage.

#### 5.1.4.7 Gefrieren und Kühlen

**Für alle Anlagen der Nahrungsmittelindustrie, in denen Produkte eingefroren oder gekühlt werden, umfassen die BVT die Erfüllung der folgenden Punkte:**

- 1 Vermeidung der Emission von Stoffen, die die Ozonschicht schädigen, z. B. durch Verzicht auf halogenierte Substanzen als Kühlmittel (siehe Abschnitt 4.1.9.3)
- 2 Betrieb klimatisierter und gekühlter Bereiche nicht kälter als notwendig (siehe Abschnitt 4.2.15.1)
- 3 Optimierung des Verdichterdrucks (siehe Abschnitt 4.2.11.2)
- 4 Regelmäßiges Abtauen des gesamten Systems (siehe Abschnitt 4.2.15.3)
- 5 Sauberhalten des Kühlers (siehe Abschnitt 4.2.11.3)
- 6 Versorgung der Kühler mit möglichst kalter Luft (siehe Abschnitt 4.2.11.3)
- 7 Optimierung der Kondensationstemperatur (siehe Abschnitt 4.2.11.3)
- 8 Einsatz der automatischen Abtauung bei Kühlverdampfern (siehe Abschnitt 4.2.15.5)
- 9 Betrieb ohne automatische Abtauung während kurzer Produktionsstopps (siehe Abschnitt 4.2.11.7)
- 10 Minimierung der Übertragungs- und Belüftungsverluste aus Kühlräumen und Kühlhäusern (siehe Abschnitt 4.2.15.2).

#### 5.1.4.8 Kühlung

**Für alle Anlagen der Nahrungsmittelindustrie, in denen Produkte gekühlt werden, umfassen die BVT die Erfüllung der folgenden Punkte:**

- 1 Optimierung des Betriebs der Kühlwassersysteme, um übermäßiges Abblasen des Kühlturms zu vermeiden (siehe Abschnitt 4.1.5)
- 2 Installation eines Plattenwärmetauschers zum Vorkühlen von Eiswasser mit Ammoniak vor dem endgültigen Kühlen in einem Eiswassersammeltank mit Röhrenverdampfer (siehe Abschnitt 4.2.10.1)
- 3 Wärmerückgewinnung aus der Kühlanlage. Es können Wassertemperaturen von 50-60 °C erreicht werden (siehe Abschnitt 4.2.13.5)

#### 5.1.4.9 Verpacken

**Für alle Anlagen der Nahrungsmittelindustrie, in denen Produkte verpackt werden, umfassen die BVT die Erfüllung der folgenden Punkte:**

- 1 Optimierung der Verpackung, auch in Bezug auf Gewicht und Volumen des Materials und den Anteil an Recyclingmaterial, um die verwendete Menge zu verringern und Abfall zu minimieren (siehe Abschnitt 4.2.12.2)
- 2 Materialeinkauf in großen Mengen (siehe Abschnitt 4.1.7.2)
- 3 Getrennte Sammlung von Verpackungsmaterial (siehe Abschnitt 4.2.12.3)
- 4 Minimierung des Überlaufens während des Verpackungsvorgangs (siehe Abschnitt 4.2.12.6)

### 5.1.4.10 Erzeugung und Verwendung von Energie

**Die BVT umfassen die Erfüllung der folgenden Punkte:**

- 1 Bei Anlagen, in denen die erzeugte Wärme und der erzeugte Strom verwendet werden, z. B. bei der Herstellung von Zucker, der Produktion von Milchpulver, der Trocknung von Molke, der Produktion von Instantkaffee, beim Brauen und Destillieren, beim Einsatz von Kraft-Wärmekopplungsanlagen (Blockheizkraftwerke) in neuen oder entsprechend modifizierten Anlagen oder im Falle der Erneuerung der Energiesysteme (siehe Abschnitt 4.2.13.1).
- 2 Verwendung von Wärmepumpen für die Wärmerückgewinnung aus unterschiedlichen Quellen (siehe Abschnitt 4.2.13.4)
- 3 Ausschalten der Geräte, wenn sie nicht benötigt werden (siehe Abschnitt 4.2.13.6)
- 4 Minimierung der Belastung der Motoren (siehe Abschnitt 4.2.13.7)
- 5 Minimierung der Motorverluste (siehe Abschnitt 4.2.13.8)
- 6 Einsatz drehzahlverstellbarer Antriebe zur Verringerung der Belastung von Ventilatoren und Pumpen (siehe Abschnitt 4.2.13.10)
- 7 Thermische Isolierung, z. B. von Leitungen, Behältern und Geräten, die für Transport, Lagerung und Behandlung von Stoffen bei Temperaturen über oder unter Raumtemperatur dienen oder bei Geräten, die für Erwärmungs- oder Kühlvorgänge verwendet werden (siehe Abschnitt 4.2.13.3)
- 8 Einsatz von Frequenzreglern bei Motoren (siehe Abschnitt 4.2.13.9)

### 5.1.4.11 Verwendung von Wasser

**Falls Grundwasser verwendet wird, umfassen die BVT die Erfüllung des folgenden Punktes:**

- 1 Begrenzung der Entnahme von Grundwasser auf die wirklich notwendigen Mengen (siehe Abschnitt 4.2.14.1).

### 5.1.4.12 Druckluftsysteme

**Für die Erzeugung von Druckluft umfassen die BVT die Erfüllung der folgenden Punkte:**

- 1 Überwachung und, falls möglich, Reduzierung des Drucks (siehe Abschnitt 4.2.16.1)
- 2 Optimierung der Temperatur der zugeführten Luft (siehe Abschnitt 4.2.16.2)
- 3 Montage von Schalldämpfern an Luften- und -auslässen, um Lärmpegel zu senken (siehe Abschnitt 4.2.16.3).

### 5.1.4.13 Dampfsysteme

**Für Dampfsysteme umfassen die BVT die Erfüllung der folgenden Punkte:**

- 1 Maximierung des Kondensatrücklaufs (siehe Abschnitt 4.2.17.1)
- 2 Vermeidung von Entspannungsdampfverlusten beim Kondensatrücklauf (siehe Abschnitt 4.2.17.2)
- 3 Stilllegung nicht benutzter Leitungen (siehe Abschnitt 4.2.17.3)
- 4 Verbesserung der Kondensatableitung (siehe Abschnitt 4.1.5)
- 5 Reparatur von Dampflecks (siehe Abschnitt 4.1.5)
- 6 Minimierung des Abblasens des Kessels (siehe Abschnitt 4.2.17.4).

## 5.1.5 Verminderung von Abluftemissionen

Emissionen in die Luft entstehen bei verschiedenen Produktions- und Reinigungsvorgängen und bei der Trocknung von Produkten der Nahrungsmittelindustrie.

Es sollten in die Verfahren integrierte BVT angewendet werden, die die Luftemissionen durch Auswahl und Verwendung von Stoffen und Verfahren minimieren. Falls weitere Kontrollen notwendig sind, könnten dann Verfahren zur Verminderung der Luftemissionen gewählt werden.

**Zur Vermeidung von Luftemissionen aus Anlagen der Nahrungsmittelindustrie umfassen die BVT die Erfüllung der folgenden Punkte:**

- 1 Einsatz und Beibehaltung einer Kontrollstrategie für Luftemissionen (siehe Abschnitt 4.4.1), einschließlich
  - 1.1 der Definition des Problems (siehe auch Abschnitte 4.4.1.1 und 4.4.1.1.1)
  - 1.2 einer Bestandsliste der Emissionen der Anlage, einschließlich z. B. bei Ausnahmebetrieb (siehe Abschnitte 4.4.1.2 und 4.4.1.2.1)
  - 1.3 der Messung der Hauptemissionen (siehe Abschnitte 4.4.1.3 und 4.4.1.3.1)
  - 1.4 der Beurteilung und Auswahl der Kontrollverfahren für Luftemissionen (siehe Abschnitt 4.4.1.4)
- 2 Auffangen der Abgase, Gerüche und Stäube am Ort der Entstehung (siehe Abschnitt 4.4.3.2) und Ableitung zu Behandlungs- oder Verminderungsanlagen (siehe Abschnitt 4.4.3.3)
- 3 Optimierung der Verfahren zum Starten und Herunterfahren der Anlagen zur Verminderung der Luftemissionen, um sicherzustellen, dass sie immer über den gesamten Zeitraum, in dem eine Vermeidung erforderlich ist, effektiv betrieben werden (siehe Abschnitt 4.4.3.1)
- 4 Falls nicht anders festgelegt, Einsatz von Vermeidungsmaßnahmen, wenn die Luftemissionen mit Hilfe prozessintegrierter BVT zur Minimierung von Luftemissionen durch Auswahl und Einsatz von Stoffen und Anwendung von Techniken nicht auf die Emissionswerte von 5-20 mg/Nm<sup>3</sup> für trockenen Staub, 35-60 mg/Nm<sup>3</sup> für nassen/klebrigen Staub und <50 mg/Nm<sup>3</sup> für TOC gesenkt werden können. Dieses Dokument berücksichtigt keine spezifischen Emissionen aus Verbrennungsanlagen mit Dampf-/Stromerzeugung in Anlagen der Nahrungsmittelindustrie. Daher sollen diese Werte auch nicht die mit den BVT erreichbaren Emissionswerte dieser Verbrennungsanlagen darstellen. Einige Verfahren zur Verminderung der Luftemissionen sind in den Abschnitten 4.4 bis 4.4.3.12 beschrieben
- 5 Einsatz von Verminderungstechniken, wenn prozessintegrierte BVT die Geruchsbelästigung nicht verhindern können. Viele der in Abschnitt 4.4 beschriebenen Verfahren sind auf die Geruchsverminderung anwendbar.

### 5.1.6 Abwasserbehandlung

Die Behandlung von Abwasser erfolgt durch nachsorgende Verfahren zur Vermeidung und Minderung der Verunreinigung des Wassers. Abwasser entsteht bei verschiedenen Vorgängen sowohl durch den Wasserverbrauch bei Produktion und Reinigung als auch bei der Trocknung von Produkten der Nahrungsmittelindustrie.

Es sollten vorrangig prozessintegrierte BVT eingesetzt werden, die sowohl den Verbrauch als auch die Verunreinigung des Wassers reduzieren. Erst danach kann die Auswahl der Abwasserbehandlungsverfahren getroffen werden.

Es konnte nicht abschließend entschieden werden, ob es besser ist, das Abwasser aus Anlagen der Nahrungsmittelindustrie auf dem Betriebsgelände oder außerhalb zu behandeln, mit Ausnahme einiger Abwasservorbehandlungsverfahren.

**Für die Behandlung der Abwässer aus Anlagen der Nahrungsmittelindustrie umfassen die BVT eine geeignete Kombination der folgenden Punkte:**

- 1 Entfernen der groben Feststoffe mittels Rechen/Sieben (siehe Abschnitt 4.5.2.1) am Anfallort
- 2 Fettentfernung mittels Fettabscheider (siehe Abschnitt 4.5.2.2) in der Anlage der Nahrungsmittelindustrie, sofern das Abwasser tierische oder pflanzliche lipophile Stoffe enthält
- 3 Vergleichmäßigung (Misch- und Ausgleichsbecken) von Abwasserabfluss und -belastung (siehe Abschnitt 4.5.2.3)
- 4 Einsatz eines Neutralisationsverfahrens (siehe Abschnitt 4.5.2.4) bei stark alkalischem oder saurem Abwasser
- 5 Einsatz von Sedimentationsverfahren (siehe Abschnitt 4.5.2.5) bei Abwasser, das suspendierte Feststoffe enthält
- 6 Einsatz von Entspannungsflotationsverfahren, falls geeignet (siehe Abschnitt 4.5.2.6)
- 7 Einsatz von biologischen Behandlungsverfahren. Aerobe und anaerobe Verfahren, die im Bereich der Nahrungsmittelproduktion eingesetzt werden, sind in den Abschnitten 4.5.3.1 bis 4.5.3.3.2 beschrieben

- 8 Nutzung von CH<sub>4</sub>-Gas, das während der anaeroben Behandlung entsteht, zur Gewinnung von Wärme und/oder Energie (siehe Abschnitt 4.5.3.2)

Falls in diesem Kapitel nicht anders erwähnt, sind die in Tabelle 5.1 aufgeführten Emissionswerte Richtwerte, die beim Einsatz der allgemein als BVT angesehenen Techniken erreicht werden können (siehe Abschnitt 4.5.1.1). Sie repräsentieren nicht unbedingt die zurzeit in der Branche erzielten Werte, sondern beruhen vielmehr auf dem Fachurteil der TAG.

| Parameter   | Konzentration (mg/l) |
|---|----------------------|
| BSB <sub>5</sub>  | <25                  |
| CSB   | <125                 |
| TSS   | <50                  |
| pH-Wert   | 6 – 9                |
| Fette und Öle   | <10                  |
| Gesamtstickstoff  | <10                  |
| Gesamtphosphor  | 0,4 – 5              |
| Für BSB <sub>5</sub> und CSB können bessere Werte erreicht werden. Unter Berücksichtigung der lokalen Bedingungen ist es nicht immer möglich oder kostengünstig, die aufgeführten Werte für Gesamtstickstoff und Gesamtphosphor zu erreichen. |                      |

**Tabelle 5.1: Typische Qualität von Abwasser aus der Nahrungsmittelproduktion nach Behandlung [140, World Bank (IBRD), et al., 1998, 199, Finland, 2003]**

Ein Mitgliedsstaat<sup>40</sup> stimmt nicht mit der Fußnote in Tabelle 5.1 überein, denn er vertritt die Auffassung, dass Abweichungen von den BVT – z. B. aufgrund lokaler Gegebenheiten – ausschließlich erlaubt sind, um für strengere Anforderungen in den Genehmigungen zu sorgen.

**Falls eine weitere Behandlung zum Erreichen dieser Werte oder zur Einhaltung spezieller Grenzwerte bei der Weiterleitung erforderlich ist, stehen die folgenden Techniken zur Verfügung:**

- 9 Biologische Entfernung von Stickstoff (siehe Abschnitte 4.5.4.1 und 4.5.4.7)  
10 Ausfällungsverfahren zur Entfernung von Phosphor (siehe Abschnitt 4.5.2.9) gleichzeitig mit der Belebtschlammbehandlung, sofern diese eingesetzt wird (siehe Abschnitt 4.5.3.1.1)  
11 Einsatz von Filtrationsverfahren als dritte Reinigungsstufe für Abwasser (siehe Abschnitt 4.5.4.5)  
12 Entfernung gefährlicher und prioritärer Schadstoffe (siehe Abschnitt 4.5.4.4)  
13 Einsatz von Membranfiltrationsverfahren (siehe Abschnitt 4.5.4.6).

**Falls die Qualität des Abwassers dessen Wiederverwendung in der Nahrungsmittelproduktion möglich macht, umfassen die BVT die Erfüllung der folgenden Punkte:**

- 14 Wiederverwendung von Wasser, das ohne den Einsatz von aktivem Chlor sterilisiert und desinfiziert wurde (siehe Abschnitte 4.5.4.8, 4.5.4.8.1 und 4.5.4.8.2) und das den Normen der Direktive des Rates 98/83/EC [66, EC, 1998] entspricht.

Typische Anwendungsbereiche für Abwasserbehandlungsverfahren im Bereich der Nahrungsmittelproduktion sind in Tabelle 4.45 angegeben.

**Zu den BVT für die Behandlung von Abwasserschlämme gehört der Einsatz eines der folgenden Verfahren oder einer Kombination daraus:**

- 15 Stabilisierung (siehe Abschnitt 4.5.6.1.2)  
16 Eindickung (siehe Abschnitt 4.5.6.1.3)  
17 Entwässerung (siehe Abschnitt 4.5.6.1.4)

<sup>40</sup> Anm. d. UBA-Bearb.: Deutschland

- 18 Trocknung (siehe Abschnitt 4.5.6.1.5), falls natürliche Wärme oder Wärme, die aus Prozessen in der Anlage rückgewonnen wird, eingesetzt werden kann.

Es wurden keine BVT für die Verwendung oder Entsorgung von Abwasserschlämmen identifiziert. Verfügbare Möglichkeiten werden in Abschnitt 4.5.6.1 aufgezählt, aber nicht beschrieben.

### 5.1.7 Unbeabsichtigte Freisetzungen

**Zur Vermeidung von Unfällen und zur Minimierung der Umweltschäden insgesamt umfassen die BVT ganz allgemein die Erfüllung der folgenden Punkte:**

- 1 Identifizierung möglicher Ursachen/Verursacher von Vorfällen/unbeabsichtigten Freisetzungen, die die Umwelt schädigen können (siehe Abschnitt 4.6.1)
- 2 Beurteilung der Wahrscheinlichkeit, mit der die identifizierten möglichen Vorfälle/unbeabsichtigten Freisetzungen auftreten können und ihrer Schwere, wenn sie tatsächlich auftreten, d. h. Durchführung einer Risikobeurteilung (siehe Abschnitt 4.6.2)
- 3 Identifizierung derjenigen möglichen Vorfälle/unbeabsichtigten Freisetzungen, für deren Verhinderung zusätzliche Kontrollen notwendig sind (siehe Abschnitt 4.6.3)
- 4 Identifizierung und Implementierung von Kontrollmaßnahmen, die notwendig sind, um Unfälle zu vermeiden und ihre Schäden für die Umwelt zu minimieren (siehe Abschnitt 4.6.4)
- 5 Entwicklung, Implementierung und regelmäßiges Testen eines Notfallplans (siehe Abschnitt 4.6.5)
- 6 Untersuchung aller Unfälle und Beinahe-Unfälle und das Führen von Aufzeichnungen (siehe Abschnitt 4.6.6).

## 5.2 Zusätzliche BVT für einzelne Branchen der Nahrungsmittelproduktion

Für die Bereiche, für die keine zusätzlichen BVT festgelegt wurden, z. B. für Mühlenerzeugnisse, die Herstellung von Trockennudeln und Tierfutter, für die Herstellung von Brot, Süßwaren und Hefe, für das Mälzen, Destillieren, die Herstellung von Apfelwein, alkoholfreien Erfrischungsgetränken und Zitronensäure, gelten die allgemeinen BVT aus den Abschnitten 5.1 bis 5.1.7.

### 5.2.1 Zusätzliche BVT für den Sektor Fleisch und Geflügel

**Neben den BVT gemäß Abschnitt 5.1 bis 5.1.7 umfassen die BVT für Anlagen zur Verarbeitung von Fleisch und Geflügel die Erfüllung der folgenden Punkte:**

- 1 Auftauen von Fleisch in Luft (siehe Abschnitt 4.2.2.5)
- 2 Vermeidung der Verwendung von Scherbeneis durch Einsatz einer geeigneten Mischung aus gekühlten und gefrorenen Rohwaren (siehe Abschnitt 4.7.1.3)
- 3 Zugabe von Gewürzen und anderen festen Inhaltsstoffen aus großen Behältern und nicht aus Plastiktüten (siehe Abschnitt 4.1.7.2)
- 4 Automatische Unterbrechung der Wasserzufuhr, wenn Würstchenfüllanlagen und ähnliche Geräte während der Pausen oder bei Produktionsunterbrechungen nicht benutzt werden (siehe Abschnitt 4.1.8.4).

### 5.2.2 Zusätzliche BVT für den Sektor Fisch und Schalentiere

**Neben den BVT gemäß Abschnitt 5.1 bis 5.1.7 umfassen die BVT für Anlagen zur Verarbeitung von Fisch und Schalentieren die Erfüllung der folgenden Punkte:**

- 1 Erhaltung der Fischqualität für eine optimale Verarbeitung durch Minimierung der Lagerzeiten (siehe Abschnitt 4.1.7.3)
- 2 Verwendung von qualitativ hochwertigem Fisch durch Zusammenarbeit mit vorgeschalteten Lieferanten (siehe Abschnitt 4.7.2.3)
- 3 Durchführung regelmäßiger Wartungsprogramme (siehe Abschnitt 4.1.5), um z. B. eine effiziente Enthäutung sicherzustellen (siehe Abschnitt 4.7.2.3)

- 4 Auftauen von Makrelen durch Eintauchen in mit Wasser gefüllten Behältern, wobei Luftblasen durch das Wasser geleitet werden. Der Wasserstand wird durch Umwälzung und Füllstandsschalter (siehe Abschnitt 4.2.2.1) gehalten, wodurch ein Wasserverbrauch von  $<2 \text{ m}^3/\text{t}$  Rohfisch erreicht wird
- 5 Auftauen von Weißfisch durch Eintauchen in mit Wasser gefüllten Behältern, wobei Luftblasen durch das Wasser geleitet werden. Der Wasserstand wird durch Füllstandsschalter (siehe Abschnitt 4.2.2.2) gehalten, wodurch ein Wasserverbrauch von  $<1.8\text{-}2,2 \text{ m}^3/\text{t}$  Rohfisch erreicht wird
- 6 Auftauen von Krabben und Garnelen durch Eintauchen in Behälter, die, sofern verfügbar, mit gefiltertem Schälwasser gefüllt sind. Durch das Wasser werden Luftblasen geleitet. Der Wasserstand wird durch Umwälzung und Füllstandsschalter (siehe Abschnitt 4.2.2.1) oder nur durch Füllstandsschalter gehalten (siehe Abschnitt 4.2.2.2)
- 7 Vermeidung des Entschuppens von Fisch, der noch enthäutet wird (siehe Abschnitt 4.7.2.7)
- 8 Wenn Fisch entschuppt, d. h. später nicht noch enthäutet wird, Verwendung des umgewälzten, gefilterten Wassers aus dem Entschuppungsverfahren für die Vorspülung der Fische und richtige Einstellung des Entschuppungsgeräts durch Wiegen der richtigen Menge an Schuppen für einen bestimmten Wasserfluss (siehe Abschnitt 4.7.2.8)
- 9 Entfernung und Abtransport der Haut und des Fettes von der Enthäutungstrommel durch Absaugung (siehe Abschnitt 4.7.2.4)
- 10 Entfernung und Abtransport des Fettes und der Eingeweide der Makrelen durch Absaugung (siehe Abschnitt 4.7.2.5)
- 11 Verwendung feinmaschiger Förderbänder für den Transport von festen Produkten, Nebenprodukten und Abfällen, um ihre Trennung vom Wasser zu ermöglichen (siehe Abschnitt 4.7.2.6)
- 12 beim Filetieren:
  - 12.1 Abtrennung der Fischfilets vom Skelett mit zwei Sätzen rotierender Messer (siehe Abschnitt 4.1.8.8)
  - 12.2 Ausstattung gegebenenfalls notwendiger Wasserdüsen oder Sprühreinigungssysteme mit Sensoren, die bei Produktanwesenheit auslösen (d. h. Intervallbetrieb) (siehe Abschnitt 4.1.8.8).
  - 12.3 Eine Verringerung des Wasserverbrauchs um 60-75 % kann erzielt werden durch:
    - 12.3.1 Beseitigung unnötiger Düsen, sodass Wasser nur dort zugegeben wird, wo es erforderlich ist (siehe Abschnitt 4.1.8.8)
    - 12.3.2 Ersatz der Düsen für den Weitertransport des Fisches nach dem Schwanzschnitt durch eine mechanische Vorrichtung (siehe Abschnitt 4.1.8.8)
    - 12.3.3 Ersatz der Düsen für die Reinigung der Treibräder beim Filetiervorgang durch mechanische Vorrichtungen (siehe Abschnitt 4.1.8.8)
    - 12.3.4 Ersatz vorhandener Düsen durch Düsen mit niedrigerem Wasserverbrauch (siehe Abschnitt 4.1.8.8)
    - 12.3.5 Einsatz pulsierender Wasserdüsen, d. h. alternierendes Öffnen und Schließen der Wasserversorgung mit Hilfe eines automatischen Ventils (siehe Abschnitt 4.1.8.8)
    - 12.3.6 Ersatz der Abfallrinne durch Abfallbänder und Verschluss der Düsen in der Abfallrinne. Der Abfall wird direkt bei der Filetiermaschine vom Prozesswasser getrennt, dadurch geringere Kontaktzeiten (siehe Abschnitt 4.7.2.6)
  - 12.4 Reduzierung von Anzahl und Größe der Sprühdüsen (Wassereinsparung etwa 75%) (siehe Abschnitt 4.1.8.8).

### 5.2.3 Zusätzliche BVT für den Sektor Obst und Gemüse

**Neben den BVT gemäß Abschnitt 5.1 bis 5.1.7 umfassen die BVT für Anlagen zur Verarbeitung von Obst und Gemüse die Erfüllung der folgenden Punkte:**

- 1 Wenn eine Lagerung nicht vermieden werden kann, Minimierung der Lagerzeiten (siehe Abschnitt 4.1.7.3), und wenn die Wetterbedingungen nicht den Verderb beschleunigen und/oder die Qualität beeinträchtigen, Vermeidung der Kühlung, indem das Obst und Gemüse sowie Nebenprodukte daraus, die als Tierfutter Verwendung finden sollen, im Freien in einem sauberen überdachten Bereich oder in Behältern gelagert werden (siehe Abschnitt 4.7.3.3)
- 2 Trockene Trennung von Rohwaren, die bei der Sortierung ausgeschieden sind, und festen Rückständen (z. B. aus der Sortierung, dem Putzen, der Extraktion oder der Filtration) (siehe Abschnitt 4.1.7.6)
- 3 Auffangen von Erde in Sedimentations- und/oder Filterschritten anstelle der Einspülung in die Kläranlage (siehe Abschnitte 4.1.7.6, 4.5.2.5 und 4.5.4.5)

- 4 Schälen von Obst und Gemüse mit Dampf (diskontinuierliches Verfahren, siehe Abschnitt 4.7.3.4.2 oder kontinuierliches Verfahren, siehe Abschnitt 4.7.3.4.1) ohne Einsatz von Kaltwasser zur Kondensation des Dampfes und, falls aus technologischen Gründen eine Dampfschälung nicht in Frage kommt, Anwendung der Laugenschälung (siehe Abschnitt 4.7.3.4.6), außer wenn die Rezepturanforderungen weder mit Hilfe des einen noch des anderen Verfahrens eingehalten werden können
- 5 Kühlung von Obst und Gemüse nach dem Blanchieren und vor dem Einfrieren im kalten Wasserbad (siehe Abschnitt 4.7.3.6)
- 6 Optimierung der Wiederverwendung des Wassers mit und ohne Behandlung, je nachdem, welche Arbeitsbereiche Wasser erfordern und in welcher Qualität, damit sichergestellt ist, dass angemessene Hygiene- und Lebensmittelqualitätsstandards eingehalten werden (siehe Abschnitt 4.7.3.7).

## 5.2.4 Zusätzliche BVT für die Gewinnung und Verarbeitung pflanzlicher Öle und Fette

Neben den BVT gemäß Abschnitt 5.1 bis 5.1.7 umfassen die BVT für Anlagen zur Verarbeitung pflanzlicher Öle die Erfüllung der folgenden Punkte:

- 1 Verwendung eines Desolventizer-Toasters im Gegenstromverfahren bei der Extraktion pflanzlicher Öle (siehe Abschnitt 4.7.4.2)
- 2 Bei der Verarbeitung pflanzlicher Öle Verwendung des Dampfes aus dem Desolventizer-Toaster für die erste Stufe des Vorverdampfers der Miscella-Destillation (siehe Abschnitt 4.7.4.3)
- 3 Nutzung der exothermen Reaktionswärme aus der Härtung pflanzlicher Öle zur Erhitzung des Produkts auf die gewünschte Reaktionstemperatur und zur Erzeugung von Dampf im weiteren Verlauf der Reaktion (siehe Abschnitt 4.7.4.4) Die erreichbare Erzeugung von Energie (Dampf) beträgt 25-125 kWh/t (90-450 MJ/t) (40-200 kg/t) nicht raffinierten Öls
- 4 Verwendung von Wasserringpumpen zur Erzeugung eines zusätzlichen Vakuums für die Trocknung des Öls und zur Entgasung der Öle, auch zwecks Minimierung der Oxidation des Öls (siehe Abschnitt 4.7.4.11)
- 5 Rückgewinnung des Hexans aus den kondensierbaren Dämpfen aus dem Desolventizer-Toaster-Verfahren bei Schrotbehandlung, der Miscella-Destillation und aus der Strippingkolonne des Mineralölsystems unter Verwendung eines Hexan-Wasser-Scheiders und eines Auskochers (siehe Abschnitt 4.7.4.6)
- 6 Rückgewinnung des Hexans aus den nicht kondensierbaren Dämpfen aus dem Desolventizer-Toaster-Verfahren bei der Schrotbehandlung, der Miscella-Destillation, dem Auskocher und aus der Strippkolonne des Mineralölsystems mit Hilfe eines Mineralöl-Gaswäschers (siehe Abschnitt 4.7.4.5)
- 7 Einsatz von Zyklonen zur Verringerung der Emissionen nasser Stäube, die bei der Gewinnung pflanzlicher Öle entstehen, damit ein Staubemissionswert von <math><50 \text{ mg/Nm}^3</math> erreicht wird (siehe Abschnitt 4.7.4.10)
- 8 Raffination des Rohöls mit Hilfe der physikalischen Raffination (siehe Abschnitt 4.7.4.7.2) oder, wenn sein Gehalt an freien Fettsäuren weniger als 2% beträgt, mit Hilfe der chemischen Raffination (siehe Abschnitt 4.7.4.7.1)
- 9 Desodorierung der pflanzlichen Öle mit Hilfe eines Doppel-Gaswäschers in Kombination mit einem Durchlaufkühlsystem (siehe Abschnitt 4.7.4.12.1).

## 5.2.5 Zusätzliche BVT für Molkereien

Neben den BVT gemäß Abschnitt 5.1 bis 5.1.7 umfassen die BVT für Molkereien die Erfüllung der folgenden Punkte:

- 1 Partielle Homogenisierung der Milch (siehe Abschnitt 4.7.5.3)
- 2 Austausch der diskontinuierlichen Pasteurisatoren gegen kontinuierlich arbeitende Anlagen (siehe Abschnitt 4.7.5.5)
- 3 Einsatz regenerativer Wärmetauschverfahren bei der Pasteurisation (siehe Abschnitt 4.7.5.6)
- 4 Reduzierung der Häufigkeit der Reinigung von Zentrifugalseparatoren durch Verbesserungen der vorgeschalteten Filtration und Klärung der Milch (siehe Abschnitt 4.7.5.7)
- 5 Einsatz von „just-in-time“-Verfahren zur Abfüllung von Komponenten zur Verringerung der Verluste und zur Reduzierung der Verunreinigung des Wassers (siehe Abschnitt 4.7.5.12)

- 6 Maximierung der Rückgewinnung von verdünntem, aber anderweitig nicht kontaminiertem Produkt aus der Anfangsspülung der CIP-Reinigung, aus der Anfangs-, Ende- und Produktwechselphase des HTST-Verfahrens sowie aus dem Spülvorgang anderer Geräte und Leitungen durch on-line Überwachung des Übergangs zwischen Produkt- und Wasserphase (siehe Abschnitt 4.7.5.10). Dies kann geschehen z. B. durch Messung des Volumendurchsatzes mit Hilfe von Durchflussmessern (siehe Abschnitt 4.1.8.4) bzw. Dichtesensoren oder durch Dichtebestimmung mit Hilfe von Leitfähigkeitsmessern (siehe Abschnitt 4.1.8.5.2 ) und Streulichtsensoren zur Bestimmung der Trübung (siehe Abschnitt 4.1.8.5.3) zwecks Unterscheidung zwischen Wasser und dem Produkt
- 7 in großen Molkereien mit stark verzweigtem Leitungsnetz Verwendung mehrerer kleiner CIP-Systeme anstelle eines zentralen CIP-Systems (siehe Abschnitt 4.3.9)
- 8 Wiederverwendung von Kühlwasser, benutztem Reinigungswasser, Kondensat aus der Trocknung und Verdampfung, bei Membrantrennverfahren anfallenden Permeaten und Nachspülwasser nach der gegebenenfalls zur Herstellung des für eine Wiederverwendung erforderlichen Hygienegrads notwendigen Behandlung (siehe Abschnitt 4.7.5.16)
- 9 Erzielung der in Tabelle 5.2 (siehe Abschnitt 5.2.5.1), Tabelle 5.3 (siehe Abschnitt 5.2.5.2) und Tabelle 5.4 (siehe Abschnitt 5.2.5.5) angegebenen Werte. Dabei handelt es sich um Richtgrößen für die Werte, die durch die Anwendung von prozessintegrierten BVT erreicht werden können. Sie beruhen auf den von der TAG gemeldeten erreichten Werten. Die angegebenen Spannen spiegeln die verschiedenen Bedingungen wider, unter denen die Anlagen arbeiten. Der Energieverbrauch kann z. B. in Abhängigkeit vom Produktionsvolumen schwanken. In warmem Klima kann mehr Energie zum Kühlen verbraucht werden und umgekehrt. Wasserverbrauch und Abwasseremission können z. B. aufgrund verschiedener Produktpaletten, Chargengrößen und Reinigungsverfahren schwanken. Im Vergleich zum Wasserverbrauch kann die Abwasseremission niedriger sein, denn viele Molkereien messen die Menge des eingespeisten Kühlwassers, oft aus einem eigenen Brunnen, aber nicht die Abwasserabgabe. In warmem Klima können auch Verluste durch Verdampfung auftreten.

**5.2.5.1 Zusätzliche BVT für die Produktion von Marktmilch**

**Neben den BVT gemäß Abschnitt 5.1 bis 5.1.7 und 5.2.5 umfassen die BVT für die Herstellung von Marktmilch die Erfüllung der folgenden Punkte:**

- 1 Erzielung der in Tabelle 5.2 (siehe Abschnitt 3.3.5.1.1, 3.3.5.1.2, 3.3.5.4 und 5.2.5 Punkt 9) angegebenen Verbrauchs- und Emissionswerte

| Energieverbrauch<br>(kWh/l) | Wasserverbrauch<br>(l/l) | Abwasser<br>(l/l) |
|-----------------------------|--------------------------|-------------------|
| 0,07 – 0,2                  | 0,6 – 1,8                | 0,8 – 1,7         |

**Tabelle 5.2: Verbrauchs- und Emissionswerte bei der Herstellung von Marktmilch pro Liter angelieferter Milch**

**5.2.5.2 Zusätzliche BVT für die Produktion von Milchpulver**

**Neben den BVT gemäß Abschnitt 5.1 bis 5.1.7 und 5.2.5 umfassen die BVT für die Produktion von Milchpulver die Erfüllung der folgenden Punkte:**

- 1 Zur Herstellung von Milchpulver Einsatz mehrstufiger Verdampfer (siehe Abschnitt 4.2.9.1) mit Optimierung der Brüdenverdichtung (siehe Abschnitt 4.2.9.2) gemäß der Verfügbarkeit von Wärme und Strom in der Anlage zwecks Konzentration von flüssiger Milch vor der Sprühtrocknung und nachfolgenden Wirbelschichttrocknung, z. B. in einem integrierten Wirbelschichttrockner (siehe Abschnitt 4.7.5.8)
- 2 Anwendung eines Frühwarnfeueralarmsystems, z. B. Kohlenmonoxid-detektor, zur Verringerung der Explosionsgefahr in Sprühtrocknern (siehe Abschnitt 4.7.5.8)
- 3 Erzielung der in Tabelle 5.3 (siehe Abschnitt 3.3.5.1.1, 3.3.5.1.2, 3.3.5.4 und 5.2.5 Punkt 9) angegebenen Verbrauchs- und Emissionswerte

| Energieverbrauch<br>(kWh/l) | Wasserverbrauch<br>(l/l) | Abwasser<br>(l/l) |
|-----------------------------|--------------------------|-------------------|
| 0,3 – 0,4                   | 0,8 – 1,7                | 0,8 – 1,5         |

Tabelle 5.3: Verbrauchs- und Emissionswerte bei der Produktion von Milchpulver pro Liter angelieferter Milch

### 5.2.5.3 Zusätzliche BVT für die Herstellung von Butter

Neben den BVT gemäß Abschnitt 5.1 bis 5.1.7 und 5.2.5 umfassen die BVT für die Herstellung von Butter die Erfüllung der folgenden Punkte:

- 1 Entfernung von Butterresten aus dem Leitungssystem mit Hilfe eines abgekühlten Butterblocks, der mit Druckluft durch die Leitungen gedrückt wird (siehe Abschnitt 4.3.4)
- 2 Ausspülen des Rahmerhitzers vor der Reinigung mit Magermilch (siehe Abschnitt 4.7.5.13.1)

### 5.2.5.4 Zusätzliche BVT für die Herstellung von Käse

Neben den BVT gemäß Abschnitt 5.1 bis 5.1.7 und 5.2.5 umfassen die BVT für die Herstellung von Käse die Erfüllung der folgenden Punkte:

- 1 Verwendung der warmen Molke zum Vorwärmen der für die Käseherstellung bestimmten Milch (siehe Abschnitt 4.7.5.14.7)
- 2 Maximierung der Rückgewinnung und der Verwendung der Molke (siehe Abschnitt 4.7.5.14.4)
- 3 Absonderung der Salzmolke (darf nicht mit Süß- oder Sauermolke vermischt werden) (siehe Abschnitt 4.7.5.14.4)
- 4 Reduzierung der Fett- und Käsefeinanteile in der Molke und Sieben des Flüssigkeitsstroms zur Sammlung der Feinanteile (siehe Abschnitt 4.7.5.14.2)
- 5 Minimierung des Vorkommens von Sauermolke und Abtropfenlassen des Oberteils oder der Plattform der Salzbotliche, damit der Eintrag von Salzlösung in die Kläranlage vermieden wird (siehe Abschnitt 4.7.5.14.3)
- 6 zur Herstellung von Molkenpulver Einsatz mehrstufiger Verdampfer (siehe Abschnitt 4.2.9.1) mit Optimierung der Brüdenverdichtung (siehe Abschnitt 4.2.9.2) gemäß der Verfügbarkeit von Wärme und Strom in der Anlage zwecks Konzentration der Molke vor der Sprühtrocknung und nachfolgenden Wirbelschichttrocknung, z. B. in einem integrierten Wirbelschichttrockner (siehe Abschnitt 4.7.5.8).

### 5.2.5.5 Zusätzliche BVT für die Produktion von Speiseeis

Neben den BVT gemäß Abschnitt 5.1 bis 5.1.7 und 5.2.5 umfassen die BVT für die Herstellung von Speiseeis die Erfüllung der folgenden Punkte:

- 1 Erzielung der in Tabelle 5.4 (siehe Abschnitt 3.3.5.1.1, 3.3.5.1.2, 3.3.5.4 und 5.2.5 Punkt 9) angegebenen Verbrauchs- und Emissionswerte

| Energieverbrauch<br>(kWh/kg) | Wasserverbrauch<br>(l/kg) | Abwasser<br>(l/kg) |
|------------------------------|---------------------------|--------------------|
| 0,6 – 2,8                    | 4,0 – 5,0                 | 2,7 – 4,0          |

Tabelle 5.4: Verbrauchs- und Emissionswerte bei der Produktion von 1 kg Speiseeis

### 5.2.6 Zusätzliche BVT für die Stärkeproduktion

Neben den BVT gemäß Abschnitt 5.1 bis 5.1.7 umfassen die BVT für den Stärkesektor die Erfüllung der folgenden Punkte:

- 1 Optimierung der Wiederverwendung des Prozesswassers und/oder Kartoffelfruchtwassers bei der Herstellung von Kartoffelstärke (siehe Abschnitte 3.3.7.1, 4.1.6, 4.1.7.6 und 4.7.6.1)

- 2 Verwendung des Glutenprozesswassers (aus der Proteintrennstufe) für das Waschen von Keimen und Rohfasern und für Einweichverfahren bei der Verarbeitung von Maisstärke (siehe Abschnitt 4.1.7.8)<sup>41</sup>
- 3 Waschen des Stärkeschlammes vor der Entwässerung und Trocknung im Gegenstromverfahren (siehe Abschnitt 4.7.6.1)

### 5.2.7 Zusätzliche BVT für den Zuckersektor

**Neben den BVT gemäß Abschnitt 5.1 bis 5.1.7 umfassen die BVT für den Zuckerrübensektor die Erfüllung der folgenden Punkte:**

- 1 Wiederverwendung des Transportwassers (siehe Abschnitt 4.7.7.3)
- 2 Verwendung des Kondensats aus dem Verdampfer für die Extraktion von Zucker aus Zuckerrüben (siehe Abschnitt 4.1.7.8)
- 3 keine Trocknung der Zuckerrübenschnitzel, wenn es eine Abnahmemöglichkeit für gepresste Zuckerrübenschnitzel gibt, z. B. als Tierfutter; andernfalls Trocknung der Zuckerrübenschnitzel in Dampftrocknern (siehe Abschnitt 4.7.7.1.4) oder Hochtemperaturtrocknern (siehe Abschnitt 4.7.7.1.2) in Verbindung mit Maßnahmen zur Reduzierung von Abluftemissionen. Beim Einsatz von Hochtemperaturtrocknern umfassen die möglichen Maßnahmen zur Verringerung der Abluftemissionen z. B. die Minimierung der Menge zu trocknender kleiner Rübenteilchen, die Trocknung auf eine maximale Trockensubstanz von 91%, das mechanische Abpressen der Schnitzel vor dem Trocknen, die Minimierung der zugesetzten Melassemenge vor dem Trocknen und die Optimierung des Betriebs der Zyklone (siehe Abschnitt 4.4.3.5.2) und Sprühwäscher (siehe Abschnitt 4.4.3.5.3).

### 5.2.8 Zusätzliche BVT für den Kaffeesektor

**Neben den BVT gemäß Abschnitt 5.1 bis 5.1.7 umfassen die BVT für den Kaffeesektor die Erfüllung der folgenden Punkte:**

- 1 beim Rösten von Kaffee Rückführung der Abluft aus dem Röster wieder in den Röster (siehe Abschnitt 4.7.8.4.1)
- 2 beim Rösten von Kaffee Einsatz von Vermeidungsmaßnahmen, wenn bei leicht geröstetem Kaffee die Luftemissionen mit Hilfe prozessintegrierter BVT zur Minimierung von Abluftemissionen durch Auswahl und Einsatz von Stoffen und Anwendung von Techniken nicht auf Emissionswerte von 5-20 mg/Nm<sup>3</sup> für trockenen Staub und <50 mg/Nm<sup>3</sup> für TOC (dieser Wert ist schwieriger zu erreichen, wenn die Röstung dunkler wird, siehe Abschnitt 3.2.39.2) gesenkt werden können. Einige Verfahren zur Verminderung der Luftemissionen sind in den Abschnitten 4.4 bis 4.4.3.12 beschrieben. Die Emissionswerte für NO<sub>x</sub> wurden zu spät eingereicht, um noch vollständig von der TAG überprüft werden zu können; sie werden in Abschnitt 7.5 des Kapitels „Schlussbemerkungen“ erwähnt.
- 3 bei der Herstellung von Instantkaffee Verwendung der Wärme des heißen, flüssigen Kaffee-Extraktes zur Erwärmung von Prozesswasser vor der Extraktion und Verwendung von Gegenstrom-Wärmetauschern für die Nutzung der Wärme aus der Sprühtrocknung innerhalb des Röstbereichs (siehe Abschnitt 4.7.8.1)
- 4 bei der Herstellung von Instantkaffee nach dem Trocknungsvorgang Agglomerisierung des Staubs zur Herstellung von Granulaten, dann Rückführung des restlichen Staubs und Anwendung von Techniken zur Verminderung von Abluftemissionen (siehe Abschnitt 4.7.8.2).

### 5.2.9 Zusätzliche BVT für die Getränkeproduktion

**Neben den BVT gemäß Abschnitt 5.1 bis 5.1.7 umfassen die BVT für Anlagen zur Verarbeitung von Getränken die Erfüllung der folgenden Punkte:**

- 1 falls CO<sub>2</sub> in der Anlage eingesetzt wird, Verwendung von CO<sub>2</sub>, das entweder aus dem Fermentationsverfahren rückgewonnen wird oder als Nebenprodukt eines anderen Verfahrens anfällt zwecks

<sup>41</sup> Anm. d. UBA-Bearb.: Die Verwendung von Gluten-Prozesswasser für das Einweichverfahren bei der Verarbeitung von Maisstärke wird von der dt. Industrie vor dem Hintergrund "Zöliakie" als nicht zielführend erachtet. Hier wird möglicherweise ein an sich glutenfreies Lebensmittel ohne Not mit Kleberbestandteilen belastet.

- Vermeidung der Produktion von CO<sub>2</sub> direkt aus fossilen Brennstoffen speziell für die Verwendung in der Anlage (siehe Abschnitt 4.2.4.1)
- 2 Rückgewinnung von Hefe nach der Fermentation (siehe Abschnitt 4.7.9.3)
- 3 falls Kieselgur zur Filtration verwendet wird, Sammlung des verbrauchten Filtermaterials zwecks Optimierung der Wiederverwendung und/oder Entsorgung (siehe Abschnitt 4.7.9.4.3)
- 4 Einsatz von mehrstufigen Flaschenreinigungssystemen (siehe Abschnitt 4.7.9.5.2)
- 5 Optimierung des Wasserverbrauchs in der Spülzone der Flaschenreinigungsmaschine durch Kontrolle des Spülwasserdurchlaufs, Installation eines automatischen Ventils zur Unterbrechung der Wasserversorgung beim Anhalten der Linie und Verwendung von Frischwasser in den zwei letzten Spülventilreihen (siehe Abschnitt 4.7.9.5.4)
- 6 Wiederverwendung des Überlaufs aus der Flaschenreinigung nach Sedimentation und Filtration (siehe Abschnitt 4.7.9.5.3).

### 5.2.9.1 Zusätzliche BVT für Brauereien

**Neben den BVT gemäß Abschnitt 5.1 bis 5.1.7 und 5.2.9 umfassen die BVT für Brauereien die Erfüllung der folgenden Punkte:**

- 1 Optimierung der Wiederverwendung des Heißwassers aus der Würzekühlung (siehe Abschnitt 4.7.9.6.4) und Rückgewinnung der Wärme aus der Würzekochung (siehe Abschnitt 4.7.9.6.5)
- 2 Wiederverwendung des überlaufenden Wassers aus der Flaschenpasteurisation (siehe Abschnitt 4.7.9.5.5)
- 3 Senkung des Wasserverbrauchs auf  $0,35^{42}$ -1 m<sup>3</sup>/hl produzierten Biers (siehe Abschnitt 3.3.11.1).

### 5.2.9.2 Zusätzliche BVT für die Weinherstellung

**Neben den BVT gemäß Abschnitt 5.1 bis 5.1.7 und 5.2.9 umfassen die BVT für die Weinherstellung die Erfüllung des folgenden Punktes:**

- 1 nach der Kaltstabilisierung des Weins Wiederverwendung der alkalischen Reinigungslösung (siehe Abschnitt 4.7.9.8.1); wenn die gebrauchte alkalische Reinigungslösung nicht mehr weiter verwendet werden kann und der pH-Wert noch so hoch ist, dass der Betrieb der Kläranlage unterbrochen werden könnte, Einsatz der Selbstneutralisation (siehe Abschnitt 4.5.2.4) oder, falls pH-Werte und Zulauftrate den Betrieb der Kläranlage nicht unterbrechen werden, allmähliches Ableiten der Reinigungslösung in die Kläranlage (siehe Abschnitt 4.7.9.8.2).

<sup>42</sup> Anm. d. UBA-Bearb.: Der Wert 0,35 wird auch von europäischem Verband bestätigt. Nur Spanien hat dagegen Einspruch eingelegt und wegen des hohen Verwerfens von Grundwasser für die Bierherstellung auf den Wert 1,0 bestanden.



## 6 EMERGING TECHNIQUES

This chapter includes novel pollution prevention and control techniques that are reported to be under development and may provide future cost or environmental benefits. If available, the information includes the potential efficiency of the techniques, a preliminary cost estimate, and an indication of the time-scale before the techniques might be commercially “available”. Established techniques in other sectors that are emerging in practice within the FDM sector are not included.

### 6.1 Use of UV/ozone in absorption for odour abatement

#### Description

Ozone has been used historically as an oxidant in only a limited number of odour control applications. This is primarily because, although it is extremely reactive in the liquid phase, its reactivity in the gaseous phase is lower. A process was developed during the 1980s that enhanced the activity of ozone by the incorporation of UV light. The process uses a conventional packed bed system and a liquid recycle system. Ozone is bubbled into the sump of the absorber and the ozonated water is passed through a bank of UV lamps. Ozone in the presence of UV light produces hydroxyl radicals which are far more reactive than ozone alone. Dissolved organic compounds in the liquid phase are oxidised to carbon dioxide and water and thus the absorber liquor discharged from the system is relatively clean.

#### Achieved environmental benefits

Reduced odour emissions.

#### Applicability

Ozone systems have not been effective when applied to hot and humid airflows, e.g. when applied to a poultry processor scald tank vent.

#### Reference literature

[34, Willey A R and Williams D A, 2001]



## **7 CONCLUDING REMARKS**

### **7.1 Timing of the work**

The work on this document started with the first plenary meeting of the TWG in January 2001. The main issues discussed at this meeting were the scope of this document; the key environmental issues; how to approach the work in such a diverse sector and the identification of information required. A deadline was agreed for providing the information, i.e. in time to be included in the first draft.

The discussion about the scope led to the definition of the upstream and downstream boundaries, based on the activities listed in the Directive and the issues within the scope of other BREFs in the series. The inclusion or exclusion of sectors in this document does not, however, infer any interpretation of the Directive. For example, the discussions revealed that in some MS languages the term “food” includes animal feed and in others it does not. After some discussion, a decision was made to include the processing of animal feed in this document. Further discussions with the “Slaughterhouses and animal by-products” TWG, led to the production of petfood of animal origin being included in the scope of this document. The documents do not seek to interpret the Directive, so issues related to production capacities and decisions about where permits are required are not covered.

A first draft was issued to the TWG, for consultation, in April 2002. The consultation period lasted approximately 8 weeks. A second draft, including the proposed BAT conclusions, was sent to the TWG in May 2003. The consultation period lasted until August 2003. In September 2003, the original author left the EIPPCB and in November 2003, a new author took over the work on this document.

During 2004, the work concentrated on taking account of the comments on the second draft; developing the presentation of the information to the reader and consolidating the BAT conclusions, ensuring that they were cross-referenced to the supporting information in this document.

The final plenary meeting of the TWG was held in February 2005. The meeting concentrated on discussing the BAT conclusions and the information supporting them in this document.

After the final meeting, the BAT chapter was modified to show the changes agreed at the meeting. The “Concluding remarks” and the “Executive summary” chapters were then drafted, followed by short consultations, after which the final redrafting took place.

The wide diversity of the FDM sector has presented a special challenge to the TWG. A huge variety of raw materials are processed. Many similar products are processed in different ways, sometimes following regional recipes and many dissimilar products are processed in similar ways. The wide scope of the sector; the ongoing provision of information late in the process and the change of author all influenced the content and the preparation time of this document.

### **7.2 Level of consensus, driving forces and issues arising from the final TWG meeting**

The conclusions of the work were agreed at the final plenary meeting, with a high level of consensus being achieved. Most of the BAT are concerned with the management and operation of FDM processing. The application of most of the BAT, therefore, requires little or no investment in equipment. These “in-process BAT” can generally deliver cost savings because of improved efficiencies and reduced waste production. The emphasis on the prevention of pollution by the application of “in-process” BAT may result in minimising the amount of investment required to apply “end-of-pipe” BAT, by, e.g. reducing the scale to which it is required. For example, minimising the quantity of water used and reducing its contamination with food particles and detergents, by carrying out dry cleaning, can reduce the requirement for waste water treatment compared to hosing food from equipment and floors into drains.

The nature of the raw materials in the FDM sector and the importance of freshness, both for product quality and to prevent waste, makes collaboration between upstream and downstream partners important. It was agreed that “BAT is to seek collaboration with upstream and downstream partners, to create a chain of environmental responsibility, to minimise pollution and to protect the environment as a whole”. This is consistent with the BAT approach, not only at a site-specific level, but also on a wider scale and it may be achieved at installation level or on a wider scale via organisations representing the FDM sector.

Maintenance of acceptable hygiene standards is critical in FDM installations to guarantee product quality and food safety. This strict hygiene control and the consequent requirement for regular and frequent cleaning of FDM installations and equipment have greatly influenced the BAT conclusions, especially those related directly to cleaning. Also, the recipes of some products have influenced the environmental considerations as the application of some techniques may be necessary to ensure a certain flavour, aroma or texture and this may make other techniques inapplicable.

One split view was registered. One MS does not agree with the footnote in Tabelle 5.1, which shows FDM waste water quality after treatment. The footnote states that “Better levels of BOD<sub>5</sub> and COD can be obtained. It is not always possible or cost effective to achieve the total nitrogen and phosphorus levels shown, in view of local conditions”. The MS believes that deviations from BAT, e.g. due to local conditions, are exclusively allowed to strengthen the requirements of permits.

There were some discussions arising from new information introduced during the meeting. These are discussed in Section 1.5, which contains recommendations for further work.

When the BAT associated level for dry dust emissions from FDM installations was discussed at the final plenary meeting, the question of whether this applied to emissions from combustion power plants in FDM installations was raised. Emissions from combustion power plants had not been a subject of the information exchange before the final meeting, so it was made clear that the BAT associated emission levels are not intended to represent BAT from such combustion plants.

### **7.3 Information provided**

The TWG comprises 16 MSs and the FDM industries also form a large proportion of the group. Many of the TWG members from industry are part of the CIAA delegation. Some of the TWG members from MSs also include industry representatives. Equipment suppliers are also represented. The environmental NGOs did not participate in the work on this document.

Many reports from MSs and industry were used as sources of information in the drafting of this document, including information from example plants. The participation of individual MSs in the work, to an extent, reflected the regional distribution of the sectors. For example, several MSs participated in the work on dairies, with notable contributions from the Nordic states [42, Nordic Council of Ministers, et al., 2001], Germany [9, Verband der Deutschen Milchwirtschaft (German Dairy Association), 1999] and Italy [75, Italian contribution, 2002]. Greece, Italy, Portugal and Spain dominated the discussions about olive oil. Italy provided all of the information about pasta. Germany was one of the most active members in the information exchange process. Much of the information provided by Germany was the result of close collaboration between the German authorities and some individual FDM sectors [65, Germany, 2002], e.g. the vegetable oil and fats, dairy and brewing sectors.

CIAA and its member organisations provided most of the industry contributions. These included information about the majority of the individual FDM sectors, with the exceptions of meat; fish and shellfish, and fruit and vegetables. There is relatively little information specifically about the meat sector in this document and most of this was provided by the Nordic states [41, Nordic Council of Ministers, 2001] and Italy [89, Italian contribution, 2001, 91, Italian contribution, 2001]. The information about fish and shellfish processing came mainly from the Nordic states [28, Nordic Council of Ministers, 1997]. The main sources of information about fruit and vegetable processing were Belgium [31, VITO, et al., 2001, 32, Van Bael J., 1998] and Italy [89, Italian contribution, 2001, 91, Italian contribution, 2001].

The importance of hygiene throughout the whole FDM sector is shown by the fact that information and comments about cleaning came from several MSs and from CIAA.

Most of the information about air abatement techniques was provided by CIAA [34, Willey A R and Williams D A, 2001] and Germany [65, Germany, 2002], although this contained relatively little information about emission levels or about the application or applicability of the techniques in the overall FDM sector or the individual sectors.

A high proportion of the information about waste water and its treatment was provided by the UK [13, Environment Agency of England and Wales, 2000] and Germany [65, Germany, 2002]. Information about waste water treatment in individual sectors was provided by various MSs and industry.

Information was also gathered during site visits made during the period 2001 – 2003, i.e. before the second draft was completed. The sites visited included two dairies, one in Hungary and one in Germany; four breweries, one in Hungary, one in Finland and two in Spain; a sugar refinery in Finland; a meat processing installation in Spain; two champagne installations in France, a sugar installation practising landspreading in France and several olive oil producers in Spain. Several meetings were held with CIAA on behalf of its members. Meetings were also held with German, Finnish and Spanish TWG members and with the Brewers of Europe.

The formal consultations on the draft document also prompted the submission of a huge amount of information, relatively late in the process instead of, as requested, before the first draft. The consultations provided the main opportunities for the TWG to verify information already submitted.

Almost half of the TWG members attended the final plenary meeting. The MSs on the FDM TWG were well represented at the final plenary meeting and were active in the discussions. The industry representatives were also active. A high proportion of the industry delegation represented the sugar sector.

The information exchange and the preparation of this document has been a positive development in the prevention and control of pollution for the sectors concerned. It has provided a first-time opportunity for individual sectors to learn about techniques that have been proven to work well in others, on a Europe-wide scale. The structure of this document promotes this understanding, by focusing on the processes and practices that are common for all or many of the FDM sectors and describing their application and applicability. For example, some techniques reported for the canning of fish were recognised as being applicable for preservation in cans, bottles and jars and for foods other than fish. Consequently, some techniques originally reported for individual sectors, have been determined to be BAT in others.

## 7.4 Information imbalances and gaps

In general, there is a vast difference in the level of detail of information provided about individual FDM sectors and there are also differences in the coverage of the key environmental issues in this document.

Many of the gaps which exist may be symptomatic of the fact that before the integrated approach was applied to regulating the environmental performance of the FDM sector less monitoring was carried out, particularly of in-process consumption and emission levels. The need for more information, to identify and prioritise where improvements in performance are required and to monitor improvements, is acknowledged.

For example, there is a very low level of quantitative data about meat processing, which is a major FDM sector with installations in all of the MSs. In contrast, this document contains a lot of detail about fruit and vegetable processing, however, most of this is reported as current consumption and emission data without explanations about what in-process and/or end-of-pipe techniques were applied to achieve the levels measured.

In general, the current consumption and emission level data provided were not linked with process descriptions, operating conditions, installation capacity, sampling and analytical methods and statistical presentations. For example, for waste water, information about contaminant levels from unit operations could help to identify areas where in-process controls could be improved, whereas levels measured after mixing water from various sources, after partial or complete on-site waste water treatment, does not. Reported variations in current consumption and emission levels may reflect, e.g. variations in products and processes or differences in the application of preventive techniques. Many of the techniques have been assessed qualitatively and, due to insufficient explained data, very few BAT associated consumption and emission levels have been concluded. BAT associated levels provide useful performance levels that can be used to monitor the application of BAT. They also contribute to the consistency of permit conditions.

Energy consumption is a key environmental issue in the FDM sector, e.g. for processing operations which involve the application or removal of heat and for cold storage, to maintain freshness and to ensure food safety. Techniques which can reduce energy consumption are described in this document, but very few actual measurements of energy savings associated with the application of those techniques or about the economics of investing in techniques and the resultant cost savings were provided. Such information is helpful at installation level, when considering what techniques to apply.

Benchmarks for waste minimisation are not provided, e.g. there is no detailed information about what proportion of specified raw materials end up being used in products or by-products. The industries concerned use the terms “product”, “by-product” and “co-product”. For the purposes of identifying BAT, it is more helpful to distinguish between materials which are used and others which are disposed of as waste. The nature of the FDM sector, i.e. the production of food for human and animal consumption means that the minimisation of waste necessarily takes into consideration the important issues of hygiene, food quality and customer preferences.

Water consumption and, therefore, the recycling and re-use of water were identified as key issues in the FDM sector. Although some data were provided, these were not always well explained, e.g. it was not stated whether some water consumption data for powdered milk production, included cooling water and if so, if it is once-through or recirculated. The principles of how far water should be treated, e.g. to achieve an acceptable standard for specified re-use, or to make it drinking water standard and usable in all applications, is not dealt with well in this document as an FDM generic issue. Some detailed information about water re-use is given for fruit and vegetable processing and for dairies.

The legislative requirements and practical solutions to some environmental problems are acknowledged to be changing rapidly, e.g. with respect to the use of substances which contribute to global warming. These include some refrigerants. Further information is available on <http://www.fluorocarbons.org/>.

## 7.5 Recommendations for future work

Although the information exchange has provided an opportunity for learning which has not existed in the past, there are some gaps remaining in the information and future work could provide results which might assist in the identification of BAT when this document is reviewed. By taking such additional information into consideration, this could help installation operators and permit writers to protect the environment as a whole. This section contains recommendations for future work, both at the overall FDM sector level and at individual sector level.

Much of the data in this document are not well explained and this makes it difficult to use to compare techniques and monitor improvements. It is recommended that when consumption and emission level data are provided for the review of this document, that it be linked with process descriptions, operating conditions, sampling and analytical methods, and statistical presentations. Information provided at unit operation level would enable installation operators and permit writers to apply BAT throughout the process and minimise the amount of end-of-pipe treatment required. Examples of these gaps are mentioned in Section 7.4.

The identification of BAT for the first extraction of olive oil was discussed. The technique "Two-phase extraction of olive oil" is described in Chapter 4. This technique is widely applied and there are reported environmental benefits. After a discussion at the meeting, the TWG decided that it could not reach a conclusion about BAT for olive oil extraction. In view of the environmental impact of olive oil extraction and the recent very wide application of this technique, it is recommended that the relevant information is provided to enable a full discussion when this document is reviewed.

The issue of NO<sub>x</sub> emissions from coffee roasting was raised at the final plenary TWG meeting, for the first time in the information exchange. New information about NO<sub>x</sub> emission levels of 350 mg/Nm<sup>3</sup> for decaffeinated coffee and 700 mg/Nm<sup>3</sup> for regular coffee were introduced and proposed as BAT. Due to this issue being raised so late in the work, it was not possible for the TWG to consider whether such apparently high emission levels could be BAT and to report or comment on how they are achieved. It was reported that NO<sub>x</sub> emissions from coffee roasting is a recognised problem and that levels of 3000 mg/Nm<sup>3</sup> are emitted, unabated, from some installations. Due to the lateness in the process and the incomplete information, no BAT or BAT associated levels could be determined for minimising NO<sub>x</sub> emissions from coffee roasting installations.

It is recommended that the issue of NO<sub>x</sub> emissions from coffee roasting installations be fully considered when this document is reviewed. This will require information to be provided about the techniques used in existing installations with the range of emission levels reported, so that techniques for achieving the lower levels can be identified. This should include an explanation about the differences between the roasting of regular coffee and decaffeinated coffee. Also, due to the lower levels being so high, the further reduction of NO<sub>x</sub> emission levels from coffee roasting installations is a suggested research topic (see Section 7.6).

The risks associated with the use of EDTA have been assessed by the European Chemicals Bureau [256, European Communities European Chemicals Bureau, 2004]. The report of the risk assessment refers to the total European market for EDTA and states “A high level of usage is the dairy and drinks industry, with 50 % of the total reported tonnage”. The report discusses removal rates for some on-site WWTPs and some MWWTPs. It concludes “There is a need for limiting the risks; risk reduction measures which are already being applied shall be taken into account. This conclusion is reached because of the high emissions due to the use of EDTA in industrial detergents. The exposure near sites within dairy and beverage industry with no effective EDTA removal in their treatment plants is expected to lead to a risk for aquatic organisms”. The report then also mentions other industrial sources of EDTA emissions to water.

During the information exchange, the use of EDTA and its emission to water was acknowledged to be an ongoing problem in the FDM sector. The TWG agreed that it is BAT to minimise the use of EDTA. Throughout the work, the TWG reported that for some applications there are no known effective substitutes which can be used to completely eliminate the use of EDTA and that the effectiveness and environmental impact of some potential substitutes had not been adequately assessed. During the final TWG meeting, it was reported that EDTA is not used in dairies in the UK. The possibility of determining BAT to eliminate the use of EDTA could be greatly helped if information about alternative substances already in use was provided and research into other alternatives was undertaken, before this document is reviewed.

A number of activities, particularly in relation to vegetable processing, are seasonal. Some members of the TWG have expressed concern about the application of generic BAT to seasonal activities, due to different economic standards, although specific information about these difficulties was not provided. This issue is not well covered in this document. Information about seasonal activities should be collected in the future.

Some information was provided by the TWG after the consultation period when it was too late to take it into account. For example, late information was received about enzymatic degumming of vegetable oils and fats and enzymatic interesterification of fully hydrogenated vegetable oils and fats. Such information can be considered when this document is reviewed. It is recommended that degumming of vegetable oils be fully appraised when this document is reviewed. The TWG discussed the use of either citric acid or phosphoric acid, particularly with reference to their relative impacts on the final phosphorus content of treated waste water and their economic viability. The TWG did not reach a conclusion about which technique is BAT.

Other issues have been raised during the information exchange, but not fully appraised. It is recommended that information be provided about these for discussion when this document is reviewed. These issues include:

- as a general principle, a wider examination of the applicability of techniques reported to be applied in one sector that could be carried out in other sectors. This would optimise the opportunity for sectors to learn from each other. For example, pigging was reported for use in jam making, but it is already widely applied in the FDM sector and may be applicable as a dry cleaning technique in other FDM sectors, for which it has not yet been considered
- identification of more opportunities for by-product valorisation, to optimise the use of food, drink and milk materials and to minimise waste generation
- economic information about the costs of investing in and operating techniques and the associated direct and indirect savings, e.g. due to reduced energy or waste disposal costs, or reduced losses from unintentional losses due to leakage or spills
- identification of BAT associated with high, medium and low pressure cleaning. The TWG were unable to determine which of these techniques is BAT. Increasing the pressure can remove solid residues by physical force and potentially reduce the consumption of hot and cold water and detergents. Increasing the pressure also increases the aerosol levels produced and this can cause hygiene problems, particularly if it is necessary to carry out cleaning during production
- although many air abatement techniques are described in this document, there is very little information about their application and applicability in the FDM sector

- the application of non-thermal plasma treatment of odours in the FDM sector. There are some outstanding concerns about the reliability and performance of this technique and possible safety concerns when the technique is used to treat airstreams which may cause a fire and explosion hazard
- the production of non-alcoholic beer may result in very high discharges of condensed alcohol into the WWTP. Techniques to prevent such discharges are not described in this document
- fumigation as a source of possible fugitive emissions, e.g. the selection and use of fumigants.

## 7.6 Suggested topics for future R&D projects

The information exchange has also identified some areas where additional useful knowledge could be gained from research and development projects. These relate to the following subjects:

- some malodorous substances emitted from FDM installations are acknowledged to be harmful to the environment because, e.g. they contain VOCs. Parts of industry consider that odours in general should be considered as causing nuisance only and could be dispersed without treatment to destroy the malodorous substance. Malodorous emissions can comprise a complex mixture of unidentified substances, so it is difficult to assess the adequacy of abatement techniques. Research into the composition and harmfulness of emissions would therefore be helpful
- the lowest levels of NO<sub>x</sub> emissions reported from coffee roasting are very high (see Section 7.5). The identification of techniques for consideration in the determination of BAT for minimising NO<sub>x</sub> levels from coffee roasting installations is a suggested research topic
- alternatives to using EDTA as a cleaning agent
- the environmental benefits and costs of reverse osmosis. RO is reported as being widely used in the FDM sector, e.g. for concentration of whey, skimmed milk and fruit juices; for polishing NF permeates or evaporator condensate and in water treatment, e.g. softening and for the removal of both salt and phosphorus. The technique is reported to be effective. Its cross-media effect of high energy consumption and the cost of cleaning and replacing filters make it expensive to operate. The TWG did not reach any BAT conclusions either supporting or opposing the use of RO. Research into its environmental benefits, its cross-media effects and its economic viability would provide useful information for when this document is reviewed.

The EC is launching and supporting, through its RTD programmes, a series of projects dealing with clean technologies, emerging effluent treatment and recycling technologies and management strategies. Potentially these projects could provide a useful contribution to future BREF reviews. Readers are therefore invited to inform the EIPPCB of any research results which are relevant to the scope of this document (see also the Preface of this document).



## 8 REFERENCES

- 1 CIAA (2002). "CIAA Background Document for the Technical Working Group on the "Food and Drink" BAT Reference Document Rev. 7".
- 2 Meyer, J.; Kruska, M.; Kuhn, H.-G.; Sieberger, B.-U. and Bonczek, P. (2000). "Rationelle Energienutzung in der Ernährungsindustrie", Friedr. Vieweg & Sohn, 3-528-03173-5.
- 3 CIAA (2001). "Status Report on Food Legislation in the European Union".
- 5 Derden A Vercaemst P and Dijkmans R (1999). "Beste Beschikbare Technieken voor de groente-en fruitverwerkende nijverheid", Vlaamse BBT-Kenniscentrum VITO.
- 9 Verband der Deutschen Milchwirtschaft (German Dairy Association) (1999). "Bonn, 1999, translation of extracts and additions made 2001", VDM.
- 10 Environment Agency of England and Wales (2000). "Process Descriptions for the Food and Drink sector".
- 11 Environment Agency of England and Wales (2000). "BAT and Waste Minimisation in Food and Drink Sector", Environment Agency.
- 13 Environment Agency of England and Wales (2000). "IPPC Best Available Techniques (BAT) for Effluent Management in the Food & Drink Sector".
- 17 Envirowise (UK) and March Consulting Group (UK) (1998). "ETBPP: Reducing the Cost of Cleaning in the Food and Drink Industry Guide - GG 154", Environmental Technology Best Practice Programme, <http://www.etsu.com/etbpp>.
- 18 Envirowise (UK) & Entec UK Ltd (1999). "ETBPP: Low-Cost Process Control in Food and Drink Processing - Guide GG 220", Environmental Technology Best Practice Programme, <http://www.etsu.com/etbpp>.
- 23 Envirowise (UK) and Dames & Moore Ltd (1998). "ETBPP: Reducing the Water and Effluent Costs in Breweries - Guide GG 135", Environmental Technology Best Practice Programme, <http://www.etsu.com/etbpp>.
- 27 ATV (2000). "ATV Handbuch Industrieabwasser, Lebensmittelindustrie, 4. Auflage", Ernst Sohn Verlag, ISBN 3-433-01467-1.
- 28 Nordic Council of Ministers (1997). "BAT Best available technology in the fishing industry", Nordic Council of Ministers and Nordic Council, TemaNord 1997:579.
- 31 VITO; Derden, A.; Vercaemst, P. and Dijkmans, R. (2001). "Best Available Techniques (BAT) for the fruit and vegetable processing industry", VITO.
- 32 Van Bael J. (1998). "Memorandum on Energy Consumption in the Flemish Frozen Vegetable Sector", VITO.
- 34 Willey A R and Williams D A (2001). "Management of Odorous Emissions in the Food Industry".
- 35 OECD (2001). "The Application of Biotechnology to Industrial Sustainability", OECD.
- 37 Environment Agency of England and Wales (2000). "BAT for Cleaning. Extract from UK Interim National BAT Guidance for the Food and Drink Sector".

## References

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- 39 Verband der Deutschen Milchwirtschaft (German Dairy Association) (2001). "Comments on the first draft and associated additional information and personal communications", personal communication.
- 41 Nordic Council of Ministers (2001). "Best Available Techniques (BAT) in Nordic Slaughterhouses", TemaNord 2001:553.
- 42 Nordic Council of Ministers; Korsström, E. and Lampi, M. (2001). "BAT for Nordic dairy industry", TemaNord 2001:586.
- 43 Envirowise (UK) and Entec UK Ltd. (1999). "ETBPP: Reducing Waste for Profit in the Dairy Industry - Guide GG 242", Environmental Technology Best Practice Programme, <http://www.etsu.com/etbpp>.
- 45 Envirowise (UK) and Ashact (2001). "ETBPP: Reducing Water and Waste Costs in Fruit and Vegetable Processing - Guide GG 280", Environmental Technology Best Practice Programme, <http://www.etsu.com/etbpp>.
- 47 Envirowise (UK) and Aspinwall & Co. (1999). "ETBPP: Reducing the Cost of Packaging in the Food and Drink Industry - Guide GG 157", Environmental Technology Best Practice Programme, <http://www.etsu.com/etbpp>.
- 51 Envirowise (UK) (1998). "ETBPP: Water use in the Soft Drink Industry - Guide EG 126", Environmental Technology Best Practice Programme, <http://www.etsu.com/etbpp>.
- 52 Envirowise (UK) (2000). "ETBPP: Turning Waste into Profit - Case Study GC 150", Environmental Technology Best Practice Programme, <http://www.etsu.com/etbpp>.
- 57 Envirowise (UK) (2000). "ETBPP: Pigging Cuts Costs, Recovers Product and Reduces Effluent - Case Study GC 261", Environmental Technology Best Practice Programme, <http://www.etsu.com/etbpp>.
- 58 Envirowise (UK) (1999). "ETBPP: Cutting Water and Effluent Costs in Fish Processing - Case Study GC 202", Environmental Technology Best Practice Programme, <http://www.etsu.com/etbpp>.
- 59 Danbrew Ltd. (1996). "Environmental Management in the Brewing Industry", UNEP Industry and Environment, 92-807-1523-2.
- 60 Environment Agency of England and Wales (1998). "Money for nothing - your waste tips for free", Environment Agency.
- 61 CEFS (2001). "Guide to establishing BAT in the sugar industry", CEFS.
- 62 Envirowise (UK); EEF and Lloyds Bank (1998). "ETBPP: Waste minimisation pays: Five business reasons for reducing waste - GG 125", Environmental Technology Best Practice Programme, <http://www.etsu.com/etbpp>.
- 63 Envirowise (UK) and William Battle Associates. (1998). "ETBPP: Cutting costs by reducing waste: Running a workshop to stimulate action - GG 106", Environmental Technology Best Practice Programme, <http://www.etsu.com/etbpp>.
- 64 Environment Agency of England and Wales (2001). "Waste Minimisation - An Environmental Good Practice Guide For Industry".

- 65 Germany (2002). "Best Available Techniques Reference Document on the Food and Milk Industry", BMU, Hannover University, fdm/tm/65.
- 66 EC (1998). "Council Directive 98/83/EC on quality of water intended for human consumption", European Commission.
- 67 EC (2001). "Integrated Pollution Prevention and Control (IPPC) Reference Document on the Application of Best Available Techniques to Industrial Cooling Systems".
- 68 European confederation of organisations for testing, i., certification and prevention, (1984). "Requirements for boiler water and boiler feed water - R 54/CEOC/CP 84 Def".
- 69 Environment Agency of England and Wales (2001). "Integrated pollution prevention and control Energy efficiency - IPPC H2", Horizontal Guidance Note.
- 70 UNEP; Danish EPA and COWI (2000). "Cleaner Production Assessment in Dairy Processing", 92-807-1842-8.
- 73 CADDET UK National team (1997). "Advanced control techniques improve drying energy performance", Caddet Energy Efficiency Newsletter No.4, <http://www.caddet-ee.org/>.
- 74 Greek Ministry for the Environment, P. P. a. P. W., General Direction for the Environment, Air Pollution and Noise Control Directorate, Industrial Pollution Control Division (2001). "Food industry IPPC study".
- 75 Italian contribution (2002). "BAT candidates for dairy industry", personal communication.
- 79 Italian contribution (2001). "Dairy industry - General information", personal communication.
- 81 France (2001). "The application of effluents from the food, drink and milk industries to land", personal communication.
- 82 BMU and German Federal Ministry for Environment Nature Conservation and Reactor Safety (1986). "Technische Anleitung zur Reinhaltung der Luft vom 27 Februar 1986".
- 83 CIAA (2001). "Comments on dairy industry for the UK Document - fm No.13".
- 84 European Starch Association (2001). "Comment on the UK Document Process descriptions - fm No.10".
- 85 Environment Agency of England and Wales (2000). "BAT note on frying", personal communication.
- 86 Junta de Andalucia and Agencia de Medio Ambiente (1994). "Sistemas de obtencion de aceite de oliva sin produccion de alpechin. Situacion actual".
- 87 Ullmann (2001). "Encyclopedia of Industrial Chemistry", Wiley-VCH Verlag GmbH.
- 89 Italian contribution (2001). "Consumption & emission data for meat and fruit and vegetables sectors", personal communication.
- 90 EC (2002). "Directive of the European Parliament and of the Council on the promotion of cogeneration based on a useful heat demand in the internal energy market, COM(2002) 415 final", OJ.

## References

---

- 91 Italian contribution (2001). "Fruit & vegetable and meat processing. General information and applied technologies", personal communication.
- 92 CADDET Energy Efficiency (2000). "Saving energy with cogeneration in a brewery", CADDET Energy Efficiency Newsletter, [http://www.caddet-ee.org/nl\\_pdf/003\\_08.pdf](http://www.caddet-ee.org/nl_pdf/003_08.pdf).
- 93 EC (2000). "Guidance Document for EPER implementation", European Commission, 92-894-0279-2.
- 94 Environment Agency of England and Wales (2002). "UK comments to the first draft".
- 95 EC (2005). "Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques on Emissions from Storage".
- 96 EC (2003). "Integrated Pollution Prevention and Control (IPPC) Reference Document on the General Principles of Monitoring,".
- 99 Germany (2002). "Comments to the first draft".
- 102 UK (2002). "Comments to the first draft".
- 109 CIAA-FEDIOL (2002). "Comments to the first draft - vegetable oil".
- 115 CIAA-AAC-UFE (2002). "Comments to the first draft - starch".
- 117 CIAA-UNAFPA (2002). "Comments to the first draft - pasta".
- 118 CIAA-EDA (2002). "Comments to the first draft - dairy".
- 124 Italy (2002). "Comments to the first draft - fruit and vegetable".
- 125 Boehm, E.; Hillenbrand, T.; Herrchen, M. and Wahle, U. (2002). "Comprehensive preliminary studies and proposals for measures of risk reduction strategies for EDTA", Fraunhofer Institute.
- 126 Knepper, T. P. and et al. (2001). "Eintrage synthetischer Komplexbildner in die Gewasser", ESWE Institut for Wasserforschung, FKZ 299 24 284.
- 127 Strohmaier (2002). "Moderne Produktionstechniken and Technologien zur Herstellung von Molkenderivativen", personal communication.
- 128 CADDET Energy Efficiency (1992). "Quadruple-effect milk evaporator uses mechanical vapour recompression", IEA, OECD, <http://www.caddet-ee.org/>.
- 134 AWARENET (2002). "Tools for prevention and minimisation of agro-food wastes generation in European industry (This working draft is no longer available)", GRD1-CT-2000-28033.
- 136 CBMC - The Brewers of Europe (2002). "Guidance Note for establishing BAT in the brewing industry", CBMC.
- 139 Nielsen E.H. Lehmann, M. (2002). "BAT in the Danish sugar industry".
- 140 World Bank (IBRD); UNEP and UNIDO (1998). "Pollution prevention and abatement handbook - Toward cleaner production", World Bank, Washington, USA, [http://www-wds.worldbank.org/servlet/WDS\\_IBank\\_Servlet?pcont=details&eid=000094946\\_99040905052283](http://www-wds.worldbank.org/servlet/WDS_IBank_Servlet?pcont=details&eid=000094946_99040905052283), D:\....\WB\_cleanprod.pdf.

- 141 FEDIOL (2002). "Candidate BATs", personal communication.
- 142 IMPEL (2002). "Compilation of data on the Olives Processing Sector, with emphasis on the EU Mediterranean countries", Working document prepared in the EU IMPEL Olive Oil Project, personal communication.
- 143 CADDET Energy Efficiency (1997). "Air treatment in a cheese warehouse", twgfood\caddet\_cheese\_air.html.
- 145 Metcalf & Eddy (1991). "Wastewater engineering - Treatment, disposal and reuse, 3rd Edition", McGraw-Hill, Inc., 0-07-100824-1.
- 146 Leendertse. A. (2003). "Fact-sheet on non-thermal plasma treatment of odour", 2003 February 10.
- 147 Lehman N. and Nielsen E.H (2002). "BAT in the Danish herring industry", personal communication.
- 148 Sole (2003). "UHT milk processing - a BAT candidate technology", personal communication.
- 150 Unione Industriali Pastai Italiani (2002). "The efficient use of energy in the Italian pasta industry".
- 151 Austrian contribution (2002). "Production of citric acid", personal communication.
- 152 Austria (2002). "Comments to the 1st draft".
- 154 Ahlers J. et al. (2002). "Precautionary risk assessment and risk management of chemicals, Parts I and II", personal communication.
- 155 UBC Civil Engineering (2003). "Membrane BioReactor", <http://www.civil.ubc.ca/home/civ1525/students00/rachelui/geninfo.html>.
- 157 EC (1999). "Directive 1999/13/EC on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations", European Commission.
- 159 CIAA-CEFS (2003). "Comments on the second draft".
- 160 European Dairy Association (2002). "Consumption and emission data", EDA, personal communication.
- 161 Verband Deutscher Oelmuehlen (2003). "Contribution to Section 3.3.9.4", VDO, personal communication.
- 170 InfoMil (2001). "Netherlands emission guidelines for air (Nederlandse Emissie Richtlijn Lucht- NeR)".
- 179 Gergely, E. (2003). "Production of DDGS (Distiller's Dried Grains with Solubles)", personal communication.
- 181 EC (2003). "Integrated Pollution Prevention and Control, Draft Reference Document on Best Available Techniques in the Slaughterhouses and Animal By-products Industries".
- 182 Germany (2003). "Comments on the second draft".

## References

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- 183 CIIA-UNAFPA (2003). "Comments on the second draft".
- 184 Italy (2003). "Comments on the second draft".
- 185 CIIA-FEDIOL (2004). "Comments on the second draft".
- 186 CIIA-EUCA (2003). "Comments on the second draft".
- 188 EC (2002). "Regulation (EC) No 1774/2002 of the European Parliament and of the Council of 3 October 2002 laying down health rules concerning animal by-products not intended for human consumption".
- 189 Bockisch M (1993). "Nahrungsfette und - öle".
- 190 Health and Safety Executive (2004). "Information about Legionnaires' Disease".
- 191 EC (1992). "Council Directive 92/46/EEC of 16 June 1992 laying down the health rules for the production and placing on the market of raw milk, heat-treated milk and milk-based products", Official Journal L 268 , 14/09/1992 P. 0001 - 0032.
- 193 Leendertse A. and Haaland A.T (2003). "The performance of the APP odour abatement equipment in relation to operating conditions and measurements".
- 194 EC (1991). "Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources".
- 195 CEN (2000). "EN 13427 Packaging - requirements for the use of European standards in the field of packaging and packaging waste".
- 196 CEN (2000). "EN 13428 Packaging - requirements specific to manufacturing and composition - prevention by source reduction".
- 197 CEN (2000). "EN 13431 Packaging - requirements for packaging recoverable in the form of energy recovery, including specification of minimum calorific value".
- 198 FPME (2003). "Comments on the second draft".
- 199 Finland (2003). "Comments on the second draft".
- 200 CIIA (2003). "Comments on the second draft".
- 201 EC (1993). "Council Regulation (EEC) No 793/93 of 23 March 1993 on the evaluation and control of the risks of existing substances", Official Journal L 084 , 05/04/1993 P. 0001 - 0075.
- 202 EC (2000). "Regulation (EC) No 2037/2000 of the European Parliament and of the Council of 29 June 2000 on substances that deplete the ozone layer".
- 204 Ireland (2003). "Integrated constructed wetlands".
- 205 DoE SO and WO (1997). "Secretary of State's Guidance - Fish meal and fish oil processes", PG6/19(97).
- 206 EC (1976). "Council Directive 76/464/EEC of 4 May 1976 on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community".

- 207 EC (2000). "Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy".
- 208 CIAA-AAC-UFE (2003). "Comments on the second draft".
- 209 EC (1991). "Council Directive 91/271/EEC of 21 May 1991 concerning urban wastewater treatment".
- 211 IMPEL (2003). "IMPEL olive oil project".
- 212 The olive oil source (2004). "Disposal of olive oil processing by-products".
- 213 EC (1994). "European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste", Official Journal L 365 , 31/12/1994 P. 0010 - 0023 Finnish special edition: Chapter 15 Volume 13 P. 0266 Swedish special edition: Chapter 15 Volume 13 P. 0266.
- 215 EC (1996). "Regulation No 136/66/EEC of the Council of 22 September 1966 on the establishment of a common organisation of the market in oils and fats".
- 216 CBMC - The Brewers of Europe (2004). "Potential BATs".
- 217 EC (2003). "Integrated Pollution Prevention and Control Reference Document on Best Available Techniques in Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector".
- 218 EC (1989). "Council Regulation (EEC) No 1576/89 of 29 May 1989 laying down general rules on the definition, description and presentation of spirit drinks".
- 219 EC (2001). "Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques in the Cement and Lime Manufacturing Industries".
- 220 EC (2003). "Integrated Pollution Prevention and Control, Draft Reference Document on Best Available Techniques for Large Combustion Plants".
- 221 EC (2000). "2000/479/EC: Commission Decision of 17 July 2000 on the implementation of a European pollutant emission register (EPER) according to Article 15 of Council Directive 96/61/EC concerning integrated pollution prevention and control (IPPC) (notified under document number C(2000) 2004)".
- 222 CIAA-Federalimentare (2003). "Comments on the second draft".
- 223 Italy M. Frey (2003). "Comments on the second draft".
- 224 Portugal-FIPA (2003). "Comments on the second draft".
- 225 Hendley B. (1985). "Market for chilled foods. Food Process 52".
- 226 EC (1998). "Directive 98/8/EC of the European Parliament and of the Council of 16 February 1998 concerning the placing of biocidal products on the market".
- 227 Ockerman H. W. and Hansen C. L. (2000). "Animal by-product processing and utilisation".
- 228 Verband der Deutschen Milchwirtschaft (German Dairy Association) (1997). "EDTA in detergents".

## References

---

- 229 EC (1990). "Council Regulation (EEC) No 3037/90 of 9 October 1990 on the statistical classification of economic activities in the European Community".
- 230 Deutsches Institut für Normung p.v. (2005). "DIN 30600/28004".
- 231 Oxford University Press (2002). "Shorter Oxford English Dictionary".
- 232 Fellows P J "Food processing principles and practice".
- 233 Health and Safety Executive (2000). "Ventilation of kitchens in catering establishments", Catering sheet No 10.
- 234 UK (2003). "Comments on the second draft".
- 235 DG Environment (2003). "Comments on the second draft".
- 236 Ellis L. (2002). "Report on SERET cross-flow filtration of wines".
- 237 Caddet (1999). "The use of Pinch technology in a food processing factory".
- 239 CIAA-EDA (2003). "Comments on the second draft".
- 240 CADDET (1997). "Energy monitoring and target setting at a dairy", UK-1994-522.
- 241 ETSU (2000). "Running refrigeration plant efficiently - a cost effective guide for owners", Good practice guide 279.
- 242 Lewis D. N. (2003). "Noise abatement measures in the food industry".
- 243 EC (2003). "Directive 2003/10/EC of the European Parliament and of the Council of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise)".
- 244 Health and Safety Executive "Top 10 noise control techniques".
- 245 Barale M. (2004). "Reducing milk stone formation".
- 246 EC (2003). "Proposal for a Regulation of the European Parliament and of the Council on certain fluorinated greenhouse gases (COM(2003) 492 final - 0189/2003 COD)", (COM(2003) 492 final - 0189/2003 COD).
- 247 Verband der Deutschen Milchwirtschaft (German Dairy Association) (2003). "Comments on the second draft".
- 250 UK TWG (2004). "Space requirements for membrane bioreactors".
- 251 EC (2005). "COMMISSION REGULATION (EC) No 208/2005 of 4 February 2005 amending Regulation (EC) No 466/2001 as regards polycyclic aromatic hydrocarbons (Text with EEA relevance)".
- 252 Greece (2005). "Information about PAH levels in oils and fats".
- 253 Spain (2005). "Information about two-stage extraction of olive oil".
- 254 Denmark (2005). "Danish contribution to the final plenary TWG meeting".
- 255 Germany (2005). "German contribution to the final plenary TWG meeting".

- 256 European Communities European Chemicals Bureau (2004). "1st Priority List, Volume 49, European Union Risk Assessment Report, Edetic acid (EDTA)".
- 258 Federación Nacional de Asociaciones de la Industria de Conservas Vegetales (2005). "Chemical peach peeling".



## GLOSSARY

HINWEIS: Die deutschsprachige Version des Glossars steht ab Seite 643.

NOTE: The German version of this glossary begins on page 643.

This glossary is solely intended to assist the reader's understanding of this document. The meanings given may not necessarily reflect legal or dictionary definitions.

### Glossary of terms

|                                  |  |
|----------------------------------|--|
| Activated sludge process         | A biological waste water treatment by which bacteria that feed on organic wastes are continuously circulated and put in contact with organic waste in the presence of oxygen to increase the rate of decomposition   |
| Aeration                         | A biological process by which air is introduced to increase the oxygen concentration in liquids. Aeration may be performed by bubbling air through the liquid, spraying the liquid into the air or agitating the liquid to increase surface absorption. Blowing fresh and dry air through stored crops such as cereal grains, in order to decrease its temperature and/or humidity |
| Agronomic interests              | relating to the science of soil management and crop production   |
| Anaerobic                        | A biological process which occurs in the absence of oxygen   |
| A/O process                      | The proprietary A/O process for mainstream phosphorus removal is used for combined carbon oxidation and phosphorus removal from waste water. This process is a single-sludge suspended growth system that combines anaerobic and aerobic sections in sequence  |
| Aquifer                          | A water-bearing layer of rock (including gravel and sand) that will yield water in usable quantity to a well or spring   |
| Asbestos                         | A mineral fibre that can pollute air or water and cause cancer or asbestosis when inhaled  |
| Aseptic                          | Sterile or free of bacterial contamination   |
| Aseptic processing and packaging | Commonly used to describe food processing and packaging techniques for non-refrigerated storage or long-life products, in which packages and food products are sterilised in separate continuous systems. The sterile package is then filled with sterile product, closed and sealed under aseptic conditions  |
| Assimilative capacity            | The ability of a natural body of water to receive waste waters or toxic materials without harmful effects and without damage to aquatic life   |
| Bactericide                      | A substance used to control or destroy bacteria  |
| Baffle                           | Plate which hinders or regulates the flow of fluid   |
| Bank-filtered water              | River water abstracted from outside the river bank   |
| Biochemicals                     | Chemicals that are either naturally occurring or identical to naturally occurring substances. Examples include hormones, pheromones and enzymes. Biochemicals function as pesticides through non-toxic, non-lethal modes of action, such as disrupting the mating pattern of insects, regulating growth or acting as repellants  |
| Biocoenoses                      | Association of different organisms forming a closely integrated community. The relationship between such organisms   |
| Biodegradable                    | That can be broken down physically and/or chemically by micro-organisms. For example, many chemicals, food scraps, cotton, wool and paper are biodegradable  |
| Biodiversity                     | The number and variety of different organisms in the ecological complexes in which they naturally occur. Organisms are organised at many levels, ranging from complete ecosystems to the biochemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species and genes that must be  |

|                     |   |
|---------------------|---|
|                     | present for a healthy environment. A large number of species must characterise the food chain, representing multiple predator-prey relationships  |
| Biomass             | Organic matter available on a renewable basis. Biomass includes forest, agricultural crops and wastes, wood and wood wastes, animal wastes, livestock operation residues, aquatic plants, fast-growing trees and plants, and municipal and industrial wastes  |
| Brix degree (°brix) | Also called % DSSC (% dry soluble substances content). Concentration, expressed as sucrose content, of all substances dissolved in a liquid. X°brix is equivalent to the concentration of all substances dissolved in a juice which causes a refractometric deviation equal to that caused by a solution of X grams of sucrose per 100 grams of solution  |
| Cake                | Carbonation slurry after concentration with filter presses to about 70 % DS, e.g. with precipitated calcium carbonate   |
| Catchpot            | Fine mesh basket placed over floor drains, to prevent solids from entering the drainage system and the WWTP   |
| Caustic             | Sodium hydroxide  |
| Cephalopod          | Mollusc of class <i>Cephalopoda</i>   |
| CIP system          | Acronym for cleaning-in-place. It is a practice for cleaning tanks, pipelines, processing equipment and process lines by circulating water and cleaning solutions through them without dismantling the pipelines or equipment   |
| Coliform bacteria   | Micro-organisms found in the intestinal tracts of humans and animals. Their presence in water indicates fecal pollution and potentially dangerous bacterial contamination by disease-causing micro-organisms  |
| Conching            | Conching is a special method of kneading used in the chocolate industry   |
| Condition           | Bring to a desired state or condition   |
| Confectionery       | Sweets and sweet preparations such as cakes   |
| Cosettes            | Thin slices of sugar beet   |
| Crustacean          | Member of the Crustacea, a large class of arthropod (animal of phylum Arthropoda, with segmented body and and jointed limbs) with hard shells, mainly aquatic, e.g. crab, lobster, shrimp   |
| Culm                | The stem of a plant   |
| Decoction           | Concentration of, or extraction of the essence of a substance by boiling  |
| Defrost             | The removal of frost from the inside of a refrigerator or coldstore   |
| Degumming           | The removal of gums in vegetable oil to avoid colour and taste reversion during subsequent refining steps   |
| Eutrophication      | The pollution of a body of water by sewage, fertilisers washed from the land, and industrial wastes (inorganic nitrates and phosphates). These compounds stimulate the growth of algae, reducing the oxygen content in the water, and so killing animals with a high oxygen requirement   |
| Evisceration        | Step in the slaughter process by which the contents of the chest and belly cavities of the animals are removed  |
| Fouling             | The process of becoming dusty or clogged, e.g. in which undesirable foreign matter accumulates in a bed of filter or ion exchanger media, clogging pores and coating surfaces, thus inhibiting or delaying proper bed operation. The fouling of a heat-exchanger consists of the accumulation of dirt or other materials on the wall of a heat-exchanger, causing corrosion, roughness and ultimately leading to a lowered rate of efficiency |
| Fresh-pack          | Fruit or vegetables which have been packed fresh  |
| Fuller's earth      | Soft, greenish-grey rock resembling clay, but without clay's plasticity. It is formed largely of clay minerals, rich in montmorillonite, but a  |

|                                |   |
|--------------------------------|---|
|                                | great deal of silica is also present. Its absorbent properties make it suitable for removing oil and grease   |
| Germination                    | The process whereby seeds or spores sprout and begin to grow, also called sprouting   |
| Gram-negative bacteria         | Those bacteria which fail to stain with Gram's reaction. The reaction depends on the complexity of the cell wall and has for long determined a major division between bacterial species   |
| Herbicide                      | Any chemical toxic substance, usually used to kill specific unwanted plants, especially weeds   |
| HEPA filter                    | High efficiency particulate air filter  |
| Hull                           | Outer covering of fruit and seeds, especially pod of peas and beans, husk of grain, or green calyx of strawberry  |
| Ice-water                      | Cooled water which is then used for cooling   |
| Immission                      | Pollutant mass/concentration that is dissipated to the environment. It is measured where the environmental impact occurs.   |
| Kieselguhr                     | A light soil consisting of siliceous remains of microscopic one-celled or colonial algae, used for filtering purposes, also called diatomeaceous earth  |
| Lecithin                       | Any of a group of natural phospholipids which are esters of a phosphatidic acid with choline; such phospholipids collectively; a mixture containing these, used commercially as a food emulsifier etc.  |
| Lees                           | The sediment of wine or some other liquids  |
| Lyophilisation (freeze-drying) | The process of preserving food products by freezing them and then evaporating the water (in the form of ice) by sublimation   |
| Malt sprouts                   | The shoots which grow during germination of malt  |
| Marc                           | The residue, e.g. skins, pits and seeds, remaining after the juice has been pressed from a fruit, usually apple or grapes   |
| Mash                           | Malt mixed with hot water to form wort  |
| Miscella                       | Mixture of crude vegetable oil and hexane formed during solvent extraction of vegetable oils  |
| Mizithra cheese                | Cheese made from whey   |
| Mollusc                        | Soft-bodied and usually hard-shelled animal belonging to the phylum <i>Mollusca</i>   |
| Must                           | Any juice or liquid prepared undergoing alcoholic fermentation, e.g. grape juice or the pulp of apples or pears   |
| Native starch                  | Refined starch without any chemical and/or physical modification  |
| Nibs                           | Pieces of peeled fermented cacao beans  |
| Oenology                       | Of or pertaining to the knowledge of making wines   |
| Ostwald combustion diagram     | The Ostwald combustion diagram shows in graphical form the theoretical relationships among the products of combustion of hydrocarbons. The interdependence of CO <sub>2</sub> , O <sub>2</sub> , CO, and air-fuel ratio is given. By this, it is possible to determine the CO and air-fuel ratio when the values for CO <sub>2</sub> and O <sub>2</sub> are known   |
| Pasteurisation                 | Thermal process, treatment, or combination thereof, that is applied to food to reduce the most resistant micro-organisms of public health significance to a level that is not likely to present a public health risk under normal conditions of distribution and storage. Thermal pasteurisation treatments are time/temperature equivalent combinations to obtain a certain decimal (log) reduction of viable organisms with a reduced detrimental effect on flavour and chemistry of the food |
| Perry                          | A juice like cider, made from pears   |
| Pesticide                      | Biological, physical or chemical agent used to kill pests. In practice, the term pesticide is often applied only to chemical agents. Various pesticides are known as insecticides, nematocides, fungicides, herbicides and rodenticides, i.e., agents primarily effective against insects, nematodes (or roundworms), fungi, weeds and rodents,   |

|                                  |  |
|----------------------------------|--|
|                                  | respectively   |
| PhoStrip process                 | In the proprietary PhoStrip process for side-stream phosphorus removal, a portion of the return activated sludge process is diverted to an anaerobic phosphorus stripping tank   |
| Pomace                           | The residue, e.g. skins, pits and seeds, remaining after the juice has been pressed from, e.g. apples, pears and olives  |
| Pome                             | A fleshy fruit with a central seed-bearing core, e.g. apple  |
| Primary packaging                | Packaging conceived so as to constitute a sales unit to the final user or consumer at the point of purchase  |
| Re values (Reynolds number)      | The Reynolds number is the ratio of inertial forces, as described by Newton's second law of motion, to viscous forces. If the Reynolds number is high, inertial forces dominate, resulting on a turbulent flow. If it is low, viscous forces prevail, resulting on a laminar flow  |
| Rootlet                          | A small root, e.g. on grain during malting   |
| Sankey diagram                   | Diagrams used for displaying flows through a system, e.g. to show mass and energy flows  |
| Secondary packaging              | packaging conceived so as to constitute at the point of purchase a grouping of a certain number of sales units whether the latter is sold as such to the final user or consumer or whether it serves only as a means to replenish the shelves at the point of sale; it can be removed from the product without affecting its characteristics |
| Sparge                           | To sprinkle, e.g. water, aerate a liquid with air or inject steam. In brewing, a spray of hot water sprinkled over the malt  |
| Stabulation                      | Storing wine at low temperature  |
| Standardised milk                | Milk which has been treated to adjust the fat content to a specified percentage which depends on the milk's intended use   |
| Soil tare                        | The weight of soil, gravel and stones carried with crops when they are harvested   |
| Sump                             | A pit, well or hole used for collecting water or other fluid   |
| Surimi                           | Minced, processed fish used in the preparation of an imitation of seafood, especially shellfish  |
| Tempering                        | A process used in chocolate processing that ensures product quality and appearance; enable handling of liquid chocolate for various applications; ensure viscosity control; and enable net weight requirements to be met. Tempering is also the controlled thawing of meats  |
| Tertiary packaging               | Packaging conceived so as to facilitate handling and transport of a number of sales units or grouped packagings in order to prevent damage due to physical handling and transport  |
| Thaw                             | To unfreeze food   |
| Thermal resistance (K/W or °C/W) | The thermal resistance of an insulating material, in thermal ohms, is the R-value (a commercial unit used to measure the effectiveness of thermal insulation) divided by the thickness of the material, in meters  |
| Trub                             | A coarse coagulum of proteinaceous precipitated material which is separated from the wort as part of the brewing process   |
| Vanillin                         | A sweet smelling crystalline aldehyde which is the chief essential constituent of vanilla  |
| Van der waals forces             | Forces that exist between molecules of the same substance. These forces are much weaker than chemical bonds, and random thermal motion around room temperature can usually overcome or disrupt them. The forces operate only when molecules pass very close to each other, during collisions or near misses                                  |

|          |   |
|----------|---|
| Vinasses | A by-product that is generated when processing molasses. After the fermentable sugar in molasses has been used by the micro-organisms (e.g. yeasts) and the compounds produced have been separated out (e.g. alcohol is distilled), this is the remaining nutrient medium. The non-sugar substances that have not been assimilated and metabolic side products are in this liquid. Vinasses may be concentrated to give a solids content of 70 % by multiple-effect evaporators |
| Viscera  | The organs contained within the trunk, considered collectively, e.g. the digestive tract, heart and lungs   |
| Wort     | A sweet infusion of ground malt or other grain before fermentation, used to produce, e.g. beer and distilled malt liquors   |

### Abbreviations

|                                     |  |
|-------------------------------------|--|
| ADMS                                | Atmospheric dispersion modelling system  |
| AOCI                                | Adsorbable organic chlorine compounds  |
| AOX                                 | Adsorbable organic halogen compounds. The total concentration in milligrams per litre, expressed as chlorine, of all halogen compounds (except fluorine) present in a sample of water that are capable of being adsorbed on activated carbon   |
| ATMP                                | Amino trimethyleme phosphonic acid   |
| $a_w$                               | Water activity<br>The water activity ( $a_w$ ) of a given food is defined as<br>$a_w = p_f/p_w$ where $p_f$ and $p_w$ are the pressures of water vapour in equilibrium with the given food system and with pure water, respectively, both at the same temperature                                  |
| BAFF                                | Biological aerated flooded filter  |
| BAT                                 | Best Available Technique(s)  |
| BOD                                 | Biochemical oxygen demand: the quantity of dissolved oxygen required by micro-organisms in order to decompose organic matter. The unit of measurement is mg O <sub>2</sub> /l. In Europe, BOD is usually measured after 3 (BOD <sub>3</sub> ), 5 (BOD <sub>5</sub> ) or 7 (BOD <sub>7</sub> ) days |
| BREF                                | BAT reference document   |
| BSE                                 | Bovine spongiform encephalopathy   |
| C <sub>1</sub> , C <sub>2</sub> etc | Organic compounds indicated by the number of carbon atoms  |
| CaO                                 | Calcium oxide  |
| Ca(OH) <sub>2</sub>                 | Calcium hydroxide  |
| CCl <sub>4</sub>                    | Carbon tetrachloride   |
| CEN                                 | The European Committee for Standardisation   |
| CEFS                                | Comité Européen des Fabricants de Sucre  |
| CFC                                 | Chlorofluorohydrocarbons   |
| CFM                                 | Cross flow microfiltration   |
| CFU                                 | Colony-forming unit  |
| CGS                                 | Co-generation system (for power generation)  |
| CH <sub>4</sub>                     | Methane  |
| CHCl <sub>3</sub>                   | Trichloromethane (chloroform)  |
| CHP                                 | Co-generation of heat and power (combined heat and power)  |
| CIAA                                | Confederation of the food and drink industries of the EU   |
| CIP                                 | Cleaning-in-place  |
| Cl <sub>2</sub>                     | Chlorine   |
| CMF                                 | Cross-flow microfilter   |
| CO                                  | Carbon monoxide  |
| CO <sub>2</sub>                     | Carbon dioxide   |
| COD                                 | Chemical oxygen demand: the amount of potassium dichromate,  |

|                                |  |
|--------------------------------|--|
|                                | expressed as oxygen, required to chemically oxidise at approximately 150 °C substances contained in waste water                    |
| COP                            | Coefficient of performance   |
| DAF                            | Dissolved air flotation  |
| DC                             | Dry condensing   |
| DDGS                           | Distiller's dried grains with solubles   |
| DMRI                           | Danish Meat Research Institute   |
| DT                             | Desolventiser-toaster  |
| DTPMP                          | Diethylenetriamine pentakis methylenephosphonic acid   |
| ED                             | Electrodialysis  |
| EDTA                           | Ethylenediaminetetraacetic acid  |
| e.g.                           | For example (Latin: <i>exempli gratia</i> )  |
| EGSB                           | Expanded granular sludge blanket (reactor)   |
| EIPPCB                         | European IPPC Bureau   |
| EMAS                           | Eco-Management and Audit Scheme  |
| EMS                            | Environmental management system  |
| EP                             | Electrostatic precipitator   |
| EPA                            | US Environment Protection Agency   |
| ESP                            | Electrostatic precipitator   |
| ETBPP                          | Environmental Technology Best Practice Programme (UK)  |
| EC                             | European Commission  |
| EU                             | European Union   |
| EU-15                          | A, B, D, DK, E, EL, F, FIN, I, IRL, L, NL, P, S and UK   |
| EU-25                          | A, B, CY, CZ, D, DK, E, EE, EL, F, FIN, HU, I, IRL, L, LV, LT, MT, NL, P, PL, S, SI, SK and UK                                     |
| EUCA                           | European Coffee Association  |
| FBD                            | Fluidised bed drier  |
| FDM                            | Food, drink and milk   |
| FFS                            | Form, fill and seal  |
| Fe                             | Iron   |
| FeCl <sub>3</sub>              | Iron trichloride   |
| ffa                            | Free fatty acids   |
| F/M ratio                      | Food to micro-organism ratio   |
| FOG                            | Fats, oils and greases   |
| GE                             | A standard odour unit (OU) defined as the quantity of odour carrier in 1 m <sup>3</sup> neutral air that causes a smell perception |
| GMO                            | Genetically modified organisms   |
| HACCP                          | Hazard Analysis Critical Control Points  |
| HCFC                           | Hydrochlorofluorocarbon  |
| HCH                            | Hexachlorocyclohexane (lindane). An insecticide  |
| HCl                            | Hydrochloric acid  |
| HDPE                           | High density poly-ethylene   |
| HEPA                           | High efficiency particulate air  |
| HFC                            | Hydrofluorocarbons   |
| HHST                           | High heat short time (pasteurisation)  |
| HP                             | High pressure  |
| HPLV                           | High pressure low volume   |
| H <sub>2</sub> SO <sub>4</sub> | Sulphuric acid   |
| HTD                            | High temperature drying  |
| HTST                           | High temperature short time (pasteurisation)   |
| IC                             | Internal circulation (waste water treatment reactor)   |
| ICW                            | Integrated constructed wetlands  |
| IDS                            | Iminodisuccinat  |
| IMPEL                          | European Union Network for the Implementation and Enforcement of Environmental Law   |

|                    |   |
|--------------------|---|
| ISCST              | Industrial source complex short term (model)  |
| ISO                | International Organisation for Standardisation  |
| IPPC               | Integrated pollution prevention and control   |
| LAS                | Linear alkylated benzenesulphonacids  |
| LDPE               | Low density poly-ethylene   |
| LOEC               | Lowest observed effect concentration. The lowest experimentally determined concentration of a test substance at which adverse effects can be observed |
| LP                 | Low pressure  |
| LPG                | Liquified petroleum gas   |
| LTD                | Low temperature drying  |
| LTDM               | Long-term frequency distribution model  |
| MAP                | Modified atmosphere packing   |
| MBR                | Membrane bio-reactor  |
| MF                 | Microfiltration   |
| MGDA               | Methylglycin diacetate  |
| MLSS               | Mixed liquor suspended solids   |
| Mo                 | Molybdenum  |
| MS(s)              | Member state(s) of the European Union   |
| MVR                | Mechanical vapour recompression   |
| MWWTP              | Municipal waste water treatment plant   |
| n.d.               | No data   |
| n.e.c              | Not elsewhere classified  |
| NF                 | Nanofiltration  |
| NGO                | Non-governmental organisation   |
| NH <sub>3</sub>    | Ammonia   |
| NH <sub>4</sub>    | Ammonium  |
| NH <sub>4</sub> -N | Ammonium nitrogen   |
| NPV                | Net present value   |
| N-tot              | Total nitrogen  |
| NTA                | Nitrilotriacetate   |
| NTU                | Nephelometric turbidity units   |
| OU                 | Odour unit(s) (see also GE)   |
| P                  | Phosphorus  |
| PAH                | Polyaromatic hydrocarbons   |
| PE                 | Polyethylene  |
| PET                | Polyethylene terephthalate  |
| Pid                | Process and instrumentation diagrams  |
| PLC                | Programmable logic control  |
| PM                 | Particulate matter  |
| PP                 | Polypropylene   |
| PS                 | Polystyrene   |
| PTA                | Peseta  |
| PTFE               | Polytetrafluorethylene  |
| PVC                | Polyvinyl chloride  |
| QAC                | Quaternary ammonium compounds   |
| RBC                | Rotating biological contactors  |
| RO                 | Reverse osmosis   |
| RPM                | Rotations per minute  |
| RTD                | Research, technology and development  |
| SBAF               | Submerged biological aerated filter   |
| SBR                | Sequencing batch reactor  |
| SEC                | Specific energy consumption   |
| SME                | Small and medium enterprise(s)  |

|                 |   |
|-----------------|---|
| SO <sub>x</sub> | Sulphur oxides  |
| SO <sub>2</sub> | Sulphur dioxide   |
| SO <sub>3</sub> | Sulphur trioxide  |
| SS              | Suspended solids  |
| TDS             | Total dissolved solids  |
| TKN             | Total Kjeldahl nitrogen   |
| TOC             | Total organic carbon  |
| TS              | Total solids  |
| TSE             | Transmissible spongiform encephalopathy   |
| TSS             | Total suspended solids  |
| TVR             | Thermal vapour recompression  |
| TWG             | Technical working group   |
| UASB            | Upflow anaerobic sludge blanket (reactor)   |
| UF              | Ultrafiltration   |
| UHP             | Ultra-high pressure   |
| UHT             | Ultra-high temperature (sterilisation)  |
| UV              | Ultraviolet   |
| VOC(s)          | Volatile organic compound(s) (not limited to the definition of volatile organic compound in Council Directive 1999/13/EC) |
| WFE             | Wiped film evaporator   |
| WHB             | Waste heat boiler   |
| WHO             | World Health Organisation   |
| WWTP            | Waste water treatment plant   |
| XPP             | Expanded polypropylene  |

### Member States list

| Short Name     | Full Name  | Abbreviation |
|----------------|--|--------------|
| Austria        | Republic of Austria                                  | A            |
| Belgium        | Kingdom of Belgium                                   | B            |
| Cyprus         | Republic of Cyprus                                   | CY           |
| Czech Republic | Czech Republic                                       | CZ           |
| Germany        | Federal Republic of Germany                          | D            |
| Denmark        | Kingdom of Denmark                                   | DK           |
| Spain          | Kingdom of Spain                                     | E            |
| Estonia        | Republic of Estonia                                  | EE           |
| Greece         | Hellenic Republic                                    | EL           |
| France         | French Republic                                      | F            |
| Finland        | Republic of Finland                                  | FIN          |
| Hungary        | Republic of Hungary                                  | HU           |
| Italy          | Italian Republic                                     | I            |
| Ireland        | Ireland  | IRL          |
| Luxembourg     | Grand Duchy of Luxembourg                            | L            |
| Latvia         | Republic of Latvia                                   | LV           |
| Lithuania      | Republic of Lithuania                                | LT           |
| Malta          | Republic of Malta                                    | MT           |
| Netherlands    | Kingdom of the Netherlands                           | NL           |
| Portugal       | Portuguese Republic                                  | P            |
| Poland         | Republic of Poland                                   | PL           |
| Sweden         | Kingdom of Sweden                                    | S            |
| Slovakia       | Slovak Republic                                      | SK           |
| Slovenia       | Republic of Slovenia                                 | SI           |
| United Kingdom | United Kingdom of Great Britain and Northern Ireland | UK           |

### Currency abbreviations

| Abbreviation | Currency           |
|--------------|--------------------|
| ATS          | Austrian schilling |
| BEF          | Belgian franc      |
| CZK          | Czech koruna       |
| DEM          | German mark        |
| DKK          | Danish krone       |
| EEK          | Estonian kroon     |
| ESP          | Spanish peseta     |
| EUR          | Euro               |
| FIM          | Finish markka      |
| FRF          | French franc       |
| GBP          | Pound sterling     |
| GRD          | Greek drachma      |
| HUF          | Hungarian forint   |
| IEP          | Irish pound        |
| ITL          | Italian lira       |
| NLG          | Dutch guilder      |
| PLN          | Polish zloty       |
| PTE          | Portuguese escudo  |
| SEK          | Swedish krona      |

### Common units, measurements and symbols

| TERM    | MEANING  |
|---------|--|
| ACKWh   | kilowatt-hours (alternating current)   |
| atm     | normal atmosphere (1 atm = 101325 N/m <sup>2</sup> )   |
| bar     | bar (1.013 bar = 1 atm)  |
| barg    | bar gauge (bar + 1 atm)  |
| billion | thousand million (10 <sup>9</sup> )  |
| °C      | degree Celsius   |
| cgs     | centimetre gram second. A system of measurements now largely replaced by SI.   |
| cm      | centimetre   |
| cSt     | centistokes = 10 <sup>-2</sup> stokes  |
| d       | day  |
| °C/W    | thermal resistance   |
| dB      | Decibel. The unit of measuring noise levels  |
| dB(A)   | Noise is measured in decibels (dB). To address the way the human ear responds to sound of different frequencies (itches), an A-weighting is commonly applied, and the measurements are expressed in dB(A). Every 3 dB(A) reduction is equivalent to halving the noise level. |
| eV      | electron volt  |
| g       | gram   |
| GE      |  |
| GJ      | gigajoule  |
| Hz      | hertz  |
| h       | hour   |
| ha      | hectare (10 <sup>4</sup> m <sup>2</sup> ) (=2.47105 acres)   |
| hl      | hectolitre   |
| hPa     | hectopascal (1hPa = 100 Pa)  |
| J       | joule  |
| K       | kelvin (0 °C = 273.15 K)   |
| kA      | kiloamp(ere)   |

| TERM                  | MEANING  |
|-----------------------|--|
| kcal                  | kilocalorie (1 kcal = 4.19 kJ)   |
| kg                    | kilogramme (1 kg = 1000 g)   |
| kJ                    | kilojoule (1 kJ = 0.24 kcal)   |
| kPa                   | kilopascal   |
| kt                    | kilotonne  |
| kW                    | kilowatt   |
| kW <sub>e</sub>       | kilowatt in the form of electrical energy  |
| kWh                   | kilowatt-hour (1 kWh = 3600 kJ = 3.6 MJ = 0.0036 GJ)   |
| kWh <sub>e</sub>      | kilowatt-hour in the form of electrical energy   |
| l                     | litre  |
| m                     | metre  |
| m <sup>2</sup>        | square metre   |
| m <sup>3</sup>        | cubic metre  |
| m <sup>2</sup> .°C/W  | thermal resistance unit  |
| mg                    | milligram (1 mg = 10 <sup>-3</sup> gram)   |
| MJ                    | megajoule (1 MJ = 1000 kJ = 10 <sup>6</sup> joule)   |
| nm                    | nanometre (1 nm = 10 <sup>-9</sup> m)  |
| mm                    | millimetre (1 mm = 10 <sup>-3</sup> m)   |
| m/min                 | metres per minute  |
| mmWG                  | millimetre water gauge   |
| Mt                    | megatonne (1 Mt = 10 <sup>6</sup> tonne)   |
| Mt/yr                 | megatonnes per year  |
| mV                    | millivolts   |
| MW <sub>e</sub>       | megawatts electric (energy)  |
| MW <sub>th</sub>      | megawatts thermal (energy)   |
| ng                    | nanogram (1 ng = 10 <sup>-9</sup> gram)  |
| Nm <sup>3</sup>       | normal cubic metre (101.325 kPa, 273 K)  |
| Pa                    | pascal   |
| ppb                   | parts per billion  |
| ppm                   | parts per million (by weight)  |
| ppmv                  | parts per million (by volume)  |
| s                     | second   |
| sq ft                 | square foot (= 0.092 m <sup>2</sup> )  |
| St                    | stokes. An old, cgs unit of kinematic viscosity<br>1 St = 10 <sup>-6</sup> m <sup>2</sup> /s |
| S unit (S/m or mS/cm) | electrical conductivity (Siemens per metre or milliSiemens per centimetre)                   |
| TJ                    | terajoule (1 TJ = 10 <sup>6</sup> MJ = 10 <sup>9</sup> kJ = 10 <sup>12</sup> joule)          |
| t                     | metric tonne (1000 kg or 10 <sup>6</sup> gram)   |
| t/d                   | tonnes per day   |
| trillion              | million million (10 <sup>12</sup> )  |
| t/yr                  | tonne(s) per year  |
| V                     | volt   |
| vol-%                 | percentage by volume (also % v/v)  |
| % v/v                 | percentage by volume (also vol-%)  |
| W                     | watt (1 W = 1 J/s)   |
| wt-%                  | percentage by weight (also % w/w)  |
| % w/w                 | percentage by weight (also wt-%)   |
| yr                    | Year   |
| ΔT                    | increase of temperature  |
| ~                     | around; more or less   |
| μm                    | micrometre (1 μm = 10 <sup>-6</sup> m)   |
| Ω                     | ohm, unit of electrical resistance   |
| Ω cm                  | ohm centimetre, unit of specific resistance  |

## GLOSSAR

Dieses Glossar dient ausschließlich dazu, dem Leser das Verständnis des vorliegenden Dokumentes zu erleichtern. Die Definitionen in diesem Glossar haben keinen offiziellen Charakter und können auch von den Definitionen in anderen Publikationen wie z. B. Wörterbüchern abweichen.

### Begriffsglossar

|  |  |
|--|--|
| „Nibs“                                 | Engl., bezeichnet Stücke geschälter und fermentierter Kakaobohnen  |
| A/O-Verfahren                          | Patentiertes Verfahren zur kombinierten Kohlenstoffoxidation und Phosphateliminierung aus Abwässern im Hauptstromverfahren Dieses Verfahren verwendet einen einzigen Schlammkreislauf, bei dem eine anaerobe und ein aerobe Phase hintereinandergeschaltet sind.   |
| Abtauen                                | Entfernung unerwünschter Eisschichten, die sich in einem Kühlschrank oder Kühlhaus gebildet haben.   |
| Agronomische Interessen                | bezogen auf Bodenkunde und die Produktion von Feldfrüchten   |
| Anaerob                                | Bezeichnung für einen biologischen Abbauprozess, für den kein Luftsauerstoff erforderlich ist.   |
| Aquifer                                | Gesteinsschicht (auch Schotter und Sand), die Grundwasser führt, das in verwertbaren Mengen an einem Brunnen oder einer Quelle zur Verfügung steht.  |
| Asbest                                 | Mineralische Faser, die Luft- oder Wasserverschmutzung hervorrufen und beim Menschen durch Einatmen Krebs oder Asbestose verursachen kann.   |
| Aseptisch                              | Steril oder frei von bakterieller Kontamination  |
| Aseptische Verarbeitung und Verpackung | Verarbeitungs- und Verpackungstechniken für die ungekühlte Lagerung oder für haltbare Produkte, bei denen die Verpackungen und Lebensmittelprodukte in getrennten kontinuierlichen Systemen sterilisiert werden. Die sterile Verpackung wird dann mit sterilem Produkt abgefüllt, verschlossen und unter aseptischen Bedingungen versiegelt.   |
| Assimilative Kapazität                 | Die Fähigkeit eines Gewässers, Abwässer oder giftige Schadstoffe aufzunehmen, ohne dass es hierdurch zu einer Beeinträchtigung oder Schädigung der Wasserflora bzw. -fauna kommt.  |
| Auftauen                               | Gefrorene Nahrungsmittel auftauen  |
| Ausweiden                              | Bei der Schlachtung von Tieren die Entfernung des Inhalts der Brust- und der Bauchhöhle des Schlachtkörpers  |
| Bakterizid                             | Mittel zur Wachstumshemmung oder Abtötung von Bakterien  |
| Belagbildung                           | Vorgang der Einstaubung oder Verstopfung, wenn sich z. B. unerwünschte Fremdkörper in einem Filterbett oder Ionenaustauschmedium ansammeln, Poren verschließen und Oberflächen überziehen, wodurch die Filterfunktion beeinträchtigt wird. Bei Wärmetauschern besteht die Belagbildung in der Ansammlung von Schmutz oder anderem Material an den Platten des Wärmetauschers, was zu Korrosion, Rauheit und schließlich einem geringeren Wirkungsgrad führt. |
| Belebtschlammverfahren                 | Biologisches Verfahren der Abwasserreinigung, bei dem lebende Mikroorganismen, die sich von organischen Inhaltsstoffen des Abwassers ernähren, durch kontinuierliches Zirkulieren mit diesen organischen Stoffen und Sauerstoff in Kontakt gebracht werden, um den Abbau der organischen Inhaltsstoffe zu beschleunigen.   |

|                     |   |
|---------------------|---|
| Belüftung           | Ein biologisches Verfahren, bei dem der Sauerstoffgehalt in Flüssigkeiten durch die Zufuhr von Luft erhöht wird. Die Zufuhr kann erfolgen, indem man Luft durch die Flüssigkeit hindurchperlen lässt, die Flüssigkeit in Luft versprüht oder die Flüssigkeit aufrührt, sodass diese über ihre Oberfläche verstärkt Sauerstoff aufnimmt. Abkühlung und/oder Trocknung von gelagertem Erntegut, z. B. Getreidekörnern, durch Hindurchblasen frischer und trockener Luft.  |
| Verregnen           | Versprühen, z. B. Wasser, eine Flüssigkeit belüften, oder Dampf injizieren. Im Brauereiwesen heißer Wasserstrahl, der auf das Malz gespritzt wird.  |
| Biochemikalien      | Chemikalien, die entweder natürlich vorkommen oder mit natürlich vorkommenden Stoffen identisch sind. Hierzu gehören zum Beispiel Hormone, Pheromone und Enzyme. Biochemikalien wirken als Pestizide nicht toxisch und nicht letal, indem sie z. B. die Paarungsmuster von Insekten stören, das Wachstum regulieren oder als Insektenabwehrmittel wirken.   |
| Biodiversität       | Die Anzahl und Vielfalt verschiedener Organismen in den Ökosystemen, in denen sie natürlich vorkommen. Biodiversität umfasst mehrere Stufen der Vielfalt, von der Diversität kompletter Ökosysteme bis zur Vielfalt biochemischer Strukturen, die die molekulare Grundlage der Vererbung bilden. Insofern umfasst der Begriff der Biodiversität verschiedene Ökosysteme, Arten und Gene, die für eine gesunde Umwelt vorhanden sein müssen. Die Nahrungskette ist durch eine Vielzahl von Arten charakterisiert, die in unterschiedlichen Raubtier-Beute-Verhältnissen zueinander stehen. |
| Biologisch abbaubar | Eigenschaft eines Stoffes, physikalisch bzw. chemisch durch Mikroorganismen abgebaut werden zu können. Viele Chemikalien, Lebensmittelreste, Baumwolle, Wolle und Papier sind zum Beispiel biologisch abbaubar.   |
| Biomasse            | Organisches Material aus nachwachsenden Rohstoffen. Zur Biomasse zählen forst- und landwirtschaftliche Kulturpflanzen und Abfälle, Holz und Holzabfälle, tierische Abfälle, Rückstände aus der Nutztierverarbeitung, Wasserpflanzen, schnellwachsende Bäume und Pflanzen sowie Haus- und Industrieabfälle.  |
| Biozönose           | Stark integrierte Lebensgemeinschaft verschiedener Organismen Beziehungen zwischen diesen Organismen.   |
| Bodensatz           | Sediment, das sich in Wein und anderen Flüssigkeiten absetzt  |
| CIP-System          | CIP steht für „cleaning-in-place“. CIP-Systeme sind Systeme, mit denen Wasser und Reinigungslösungen durch Tanks, Rohrleitungen, Verarbeitungsgeräte und -ausrüstungen und Prozesslinien gepumpt werden, ohne dass hierfür die zu reinigenden Geräte demontiert werden müssen.  |
| Colibakterien       | Mikroorganismen, die im Verdauungstrakt von Menschen und Tieren vorkommen. Ihr Vorkommen in Wasser deutet auf fäkale Verschmutzung und eine möglicherweise gefährliche bakterielle Kontamination durch krankheitserregende Mikroorganismen hin.   |
| Conchieren          | Spezielles Rührverfahren in der Schokoladenherstellung  |
| Dekoktion           | Konzentration oder Extraktion des Geschmacks einer Substanz durch Aufkochen mit Wasser  |
| Eingeweide          | Allgemeine Bezeichnung für die Organe im Rumpf, wie zum Beispiel Verdauungstrakt, Herz und Lungen   |
| Eiswasser           | Gekühltes Wasser, das zu Kühlzwecken eingesetzt wird  |
| Entschleimung       | Entfernung von Schleimstoffen aus Pflanzenöl, um eine Farb- und Geschmacksreversion während der nachfolgenden Verarbeitungsschritte zu vermeiden.   |
| Erdanteil           | Das Gewicht von Erde, Kies und Steinen, die zusammen mit dem Erntegut eingebracht werden  |

|                        |  |
|------------------------|--|
| Eutrophierung          | Verschmutzung eines Gewässers durch Abwässer, vom Land eingeschwemmte Düngemittel und Industrieabwässer (anorganische Nitrate und Phosphate). Diese Verbindungen fördern die Vermehrung von Algen, was zu Sauerstoffmangel im Wasser und zum Absterben von Tieren mit hohem Sauerstoffbedarf führt.                                    |
| Feinwurzel             | Kleine Wurzel, die zum Beispiel während des Mälzvorgangs aus dem Getreidekorn keimt  |
| Filtereinsatz          | Feinmaschiger Siebkorb über Bodenabläufen, mit dem das Einwaschen von Feststoffen in das Abwassersystem und die Kläranlage verhindert wird.  |
| Filterkuchen           | z. B. Karbonisierungsschlamm, der durch Filterpressen auf etwa 70 % Trockenmasse verdichtet wurde, z. B. mit gefällttem Calciumkarbonat.   |
| Frischepack            | Obst oder Gemüse, das frisch verpackt wurde  |
| Fullererde             | Weicher, grünlich-grauer gesteinsähnlicher Ton, der jedoch nicht die plastischen Eigenschaften von Ton hat. Fullererde besteht hauptsächlich aus Tonmineralen und ist reich an Montmorillonit und auch an Silikaten. Wegen ihrer Adsorptionsfähigkeit ist Fullererde für die Entfernung von Öl und Fett gut geeignet.                  |
| Grad Brix (°Brix)      | Auch Brix oder %Brix. Maß für die lösliche Trockensubstanz in einer Flüssigkeit. x °Brix gibt die Konzentration der in einer Flüssigkeit gelösten Trockensubstanz an, die den Lichtbrechungsindex der Flüssigkeit so verändert, wie dies x g Saccharose in 100 g Lösung bewirken würden.   |
| Gramnegative Bakterien | Bakterien, die nach der Gram-Reaktion ungefärbt bleiben. Diese Reaktion hängt von der Struktur der Zellwand ab und ermöglicht schon seit langer Zeit eine grundlegende Unterscheidung zwischen verschiedenen Bakterienarten.   |
| HEPA-Filter            | Hochleistungspartikelfilter (high efficiency particulate air filter)   |
| Herbizid               | Chemisch-toxische Substanz, mit der normalerweise unerwünschte Pflanzen, insbesondere Unkräuter, selektiv abgetötet werden   |
| Immission              | Der Eintrag von Schadstoffen in die Umwelt. Immissionen werden dort gemessen, wo die Umweltauswirkung stattfindet.   |
| Keimung                | Der Prozess, bei dem Samen oder Sporen keimen und zu wachsen beginnen, auch Sprießen genannt   |
| Kernobst               | Fleischige Obstart mit einem Kerngehäuse in der Mitte der Frucht, z. B. Apfel  |
| Kieselgur              | Helle Substanz, die aus siliziumhaltigen Überresten mikroskopischer einzelliger Algen oder Algenkolonien besteht und zu Filterzwecken verwendet wird. Wird auch Diatomeenerde genannt.   |
| Konditionieren         | Etwas in einen bestimmten erwünschten Zustand bringen  |
| Konditoreierzeugnisse  | Süßigkeiten und süße Zubereitungen wie z. B. Kuchen  |
| Kopffüßer              | Tiergruppe, die zu den Weichtieren gehört. Wissenschaftlicher Name: <i>Cephalopoda</i> .   |
| Krustentiere           | Krustentiere bzw. Krebstiere (wissenschaftlicher Name: Crustacea) gehören zum Stamm der Gliederfüßer (wissenschaftlicher Name: Arthropoda), die durch einen segmentierten Körper mit gegliederten Gliedmaßen und ein versteiftes Außenskelett gekennzeichnet sind und überwiegend im Wasser leben, z. B. Krabben, Hummer und Garnelen. |
| Lecithin               | Bezeichnung für eine beliebige Gruppe natürlicher Phospholipide, die Ester aus Phosphatidsäure und Cholin darstellen; Sammelbezeichnung für alle Phospholipide; Bezeichnung für Mischungen verschiedener Phospholipide, die in der Lebensmittelindustrie als Emulgatoren usw. verwendet werden.  |

|                                   |  |
|-----------------------------------|--|
| Lyophilisation (Gefriertrocknung) | Verfahren zur Konservierung von Lebensmitteln, bei dem das Nahrungsmittel zunächst tiefgefroren und dann das (in Form von Eis) enthaltene Wasser durch Sublimation verdampft wird  |
| Maische                           | Mischung von Malz und heißem Wasser zur Bildung von Würze  |
| Malzkeimlinge                     | Die Keimlinge, die bei der Keimung von Malz wachsen  |
| Miszella                          | Gemisch aus rohem Pflanzenöl und Hexan, das sich während der Lösemittelextraktion von Pflanzenölen bildet  |
| Mizithra-Käse                     | Aus Molke hergestellter Käse   |
| Most                              | Saft oder Flüssigkeit, der oder die bei ihrer Herstellung eine alkoholische Gärung durchläuft, wie z. B. Trauben-, Apfel- oder Birnenmost.   |
| Native Stärke                     | Raffinierte Stärke, die weder chemisch noch physikalisch modifiziert wurde   |
| Natronlauge                       | Natriumhydroxid  |
| Önologie                          | Weinkunde (Weinbau und -produktion)  |
| Ostwald-Diagramm                  | Das Ostwald-Diagramm zeigt die theoretischen Beziehungen zwischen den bei der Verbrennung von Kohlenwasserstoffen anfallenden Produkten in grafischer Form. Bei gegebenen wechselseitigen Abhängigkeiten zwischen $\text{CO}_2$ , $\text{O}_2$ , $\text{CO}$ und einem gegebenen Kraftstoff-Luft-Verhältnis können der $\text{CO}$ -Gehalt und das Kraftstoff-Luft-Verhältnis bestimmt werden, wenn der $\text{CO}_2$ - und der $\text{O}_2$ -Wert bekannt sind.   |
| Pasteurisierung                   | Verfahren der kurzzeitigen Erhitzung von Lebensmitteln zum Abtöten von Mikroorganismen, die sich negativ auf die Gesundheit des Menschen auswirken können. Dabei wird die Anzahl der Mikroorganismen auf ein Maß reduziert, das unter normalen Verteilungs- und Lagerbedingungen des Lebensmittels kein Risiko mehr für die öffentliche Gesundheit darstellt. Bei den thermischen Pasteurisierungsverfahren wird die Anzahl der lebensfähigen Organismen im Lebensmittel in Abhängigkeit von den Temperatur-Zeit-Bedingungen gezielt abgesenkt, um deren schädlichen Einfluss auf das Aroma und die chemische Zusammensetzung des Lebensmittels zu minimieren. |
| Perry                             | Ein dem Apfelwein ähnlicher Birnenwein   |
| Pestizid                          | Biologisches, physikalisches oder chemisches Mittel zur Bekämpfung von Schädlingen. In der Praxis werden oft nur chemische Substanzen als Pestizide bezeichnet. Zu den Pestiziden gehören die Insektizide (gegen Insekten), Nematizide (gegen Nematoden oder Fadenwürmer), Fungizide (gegen Pilze), Herbizide (gegen Pflanzen) und Rodentizide (gegen Nagetiere).  |
| PhoStrip-Verfahren                | Bei dem patentierten PhoStrip-Verfahren für die Phosphoreliminierung aus Abwasser im Nebenstromverfahren durchläuft ein Teil des Rücklauf-Belobtschlammes anaerobe Milieubedingungen, in denen Phosphat aus der Biomasse ins Wasser abgegeben wird.  |
| Prallblech                        | Blech, mit dem der Durchfluss eines flüssigen Mediums gehemmt oder gesteuert wird  |
| Primärverpackung                  | Verpackung, die beim Kauf für den Endbenutzer oder Verbraucher eine Verkaufseinheit darstellen soll.   |
| Reynolds-Zahl                     | Die Reynolds-Zahl ist eine Kennzahl, die das Verhältnis von Trägheitskräften gemäß dem 2. Newtonschen Axiom zu Zähigkeitskräften darstellt. Wenn die Reynolds-Zahl hoch ist, überwiegen die Trägheitskräfte, was zu einer turbulenten Strömung führt. Ist die Reynolds-Zahl niedrig, überwiegen die Zähigkeitskräfte, was zu einer laminaren Strömung führt.   |
| Rübenschnitzel                    | Kleine und dünne Zuckerrübenscheiben   |
| Sankey-Diagramm                   | Diagramm, das Ströme durch ein System, z. B. den Fluss von Masse und Energie, abbildet   |

|                                 |  |
|---------------------------------|--|
| Schale                          | Die äußere, eine Frucht oder einen Samen umgebende festere Schicht, wie zum Beispiel Erbsen- und Bohnenhülsen, Getreidespelzen oder der grüne Blattkelch der Erdbeere.   |
| Sekundärverpackung              | Verpackung, die beim Kauf für den Endbenutzer oder Verbraucher die Zusammenstellung einer bestimmten Anzahl an Verkaufseinheiten darstellen soll. Dabei ist es unerheblich, ob die Verkaufseinheiten einzeln verkauft werden oder die Sekundärverpackung lediglich zum Wiederauffüllen der Regale am Verkaufspunkt dient. Die Sekundärverpackung kann entfernt werden, ohne dass hierdurch die Produkteigenschaften verändert werden.  |
| Senkgrube                       | Eine Grube oder ein Loch zum Sammeln von Wasser oder einer anderen Flüssigkeit   |
| Stabulation                     | Engl., Lagerung von Wein bei niedrigen Temperaturen  |
| Standardisierte Milch           | Milch, deren Fettgehalt je nach Verwendungszweck auf einen bestimmten Prozentsatz eingestellt wurde  |
| Stängel                         | Stiel einer Pflanze  |
| Surimi                          | Feste Masse aus zerkleinertem Fisch zur Herstellung von Meeresfrüchte-Imitaten, insbesondere Krebsfleisch-Imitat   |
| Temperieren                     | Verfahren in der Schokoladenherstellung, das konstante Qualität und gleichbleibendes Aussehen des Produkts gewährleistet, die Verarbeitung flüssiger Schokolade erleichtert, eine genaue Steuerung der Viskosität gewährleistet und das Einstellen des gewünschten Nettoproduktgewichts ermöglicht. Auch das kontrollierte Auftauen von Fleisch wird als Temperieren bezeichnet.   |
| Tertiärverpackung               | Verpackung, die die Handhabung und den Transport mehrerer Verkaufseinheiten oder zusammengestellter Verpackungen erleichtern und Transportschäden vermeiden soll.  |
| Treber                          | Der beim Pressen von Früchten (normalerweise Äpfel oder Weintrauben) übrigbleibende Rückstand aus Schalen, Steinen und Kernen.   |
| Trester                         | Der beim Pressen von beispielsweise Äpfeln, Birnen oder Oliven übrigbleibende Rückstand aus Schalen, Steinen und Kernen  |
| Trub                            | Die beim Brauvorgang von der Würze abgetrennten ausgefallten koagulierten Eiweißstoffe   |
| Uferfiltrat                     | In Ufernähe durch Brunnen gewonnenes Oberflächenwasser   |
| Van-der-Waals-Kräfte            | Bindungskräfte zwischen Molekülen des gleichen Stoffes. Diese Kräfte sind wesentlich schwächer als chemische Bindungskräfte und können durch zufällige Wärmebewegung bei Raumtemperatur beeinträchtigt bzw. aufgehoben werden. Van-der-Waals-Kräfte treten nur dann auf, wenn Moleküle sich sehr nahe kommen oder zusammenstoßen.  |
| Vanillin                        | Süß riechendes kristallines Aldehyd und Hauptaromastoff der Vanille.   |
| Vinasse                         | Nebenprodukt, das bei der Verarbeitung von Melasse entsteht. Nachdem der fermentierbare Zucker in der Melasse durch Mikroorganismen (z. B. Hefen) verbraucht und die entstandenen Verbindungen abgetrennt wurden (z. B. Alkohol durch Destillation), bleibt die Vinasse als Nährstoffmedium übrig. Diese Flüssigkeit enthält alle zuckerfreien, nicht assimilierten Stoffe und metabolischen Nebenprodukte. Vinasse kann in einem mehrstufigen Verdampfer auf einen Feststoffgehalt von 70 % aufkonzentriert werden. |
| Wärmewiderstand (K/W oder °C/W) | Der Wärmewiderstand eines Isoliermaterials ist R (handelsübliche Einheit zur Messung der Wirksamkeit einer Wärmeisolierung), geteilt durch die Dicke des Materials in Metern.  |
| Weichtiere                      | Weichtiere ( <i>Mollusca</i> ) sind durch einen weichen Körper und normalerweise eine harte Schale gekennzeichnet.   |

|       |   |
|-------|---|
| Würze | Süßer Aufguss aus gemahlenem Malz oder einem anderen unfermentierten Getreide als Vorstufe in der Herstellung von Bier und Spirituosen auf Malzbasis. |
|-------|---|

## Abkürzungen

|                                      |   |
|--------------------------------------|---|
| ADMS                                 | Ausbreitungsmodell zur Berechnung von Schadstoffkonzentrationen (atmospheric dispersion modelling system)   |
| AOCl                                 | Adsorbierbare organische Chlorverbindungen  |
| AOX                                  | Adsorbierbare organische Halogenverbindungen. Die in Milligramm Chlor pro Liter angegebene Gesamtkonzentration aller Halogenverbindungen (außer Fluor) in einer Wasserprobe, die sich an Aktivkohle anlagern können   |
| ATMP                                 | Aminotrimethylenphosphonsäure   |
| $a_w$ -Wert                          | Auch Wasseraktivität genannt. Die Wasseraktivität ( $a_w$ ) eines Nahrungsmittels ist folgendermaßen definiert:<br>$a_w = p_f/p_w,$ wobei $p_f$ der Wasserdampfdruck über einem Material und $p_w$ der Wasserdampfdruck über reinem Wasser ist, und zwar jeweils bei derselben Temperatur   |
| BAFF-Filter                          | Belüftete und geflutete Biofilter (biological aerated flooded filter)   |
| BREF                                 | BVT-Merkblatt   |
| BSB                                  | Biochemischer Sauerstoffbedarf: die Menge an gelöstem Sauerstoff, die für den aeroben mikrobiellen Abbau organischer Biomasse benötigt wird. Die Maßeinheit ist mg O <sub>2</sub> /l. In Europa wird die Sauerstoffmenge normalerweise nach 3 (BSB <sub>3</sub> ), 5 (BSB <sub>5</sub> ) oder 7 (BSB <sub>7</sub> ) Tagen gemessen. |
| BSE                                  | Rinderwahnsinn (Bovine spongiforme Enzephalopathie)   |
| BVT                                  | Beste verfügbare Technik(en)  |
| C <sub>1</sub> , C <sub>2</sub> usw. | Organische Verbindungen, gekennzeichnet durch die Zahl der Kohlenstoffatome   |
| Ca(OH) <sub>2</sub>                  | Calciumhydroxid   |
| CaO                                  | Calciumoxid   |
| CCl <sub>4</sub>                     | Tetrachlorkohlenstoff   |
| CEFS                                 | Europäischer Verband der Zuckerfabrikanten (Comité Européen des Fabricants de Sucre)  |
| CEN                                  | Europäisches Komitee für Normung (Comité Européen de Normalisation)   |
| CFC                                  | Fluorchlorkohlenwasserstoffe  |
| CFM-Technologie                      | Querstrom-Mikrofiltration (cross flow microfiltration)  |
| CFU                                  | Koloniebildende Einheit (colony-forming unit)   |
| CH <sub>4</sub>                      | Methan  |
| CHCl <sub>3</sub>                    | Trichlormethan (Chloroform)   |
| CIAA                                 | Europäischer Verband der Lebensmittelindustrie (Confederation des Industries Agro-Alimentaires de la CEE)   |
| CIP-Reinigung                        | Reinigung an Ort und Stelle (cleaning in place)   |
| Cl <sub>2</sub>                      | Chlor   |
| CMF                                  | Querstrom-Mikrofilter (cross-flow microfilter)  |
| CO                                   | Kohlenmonoxid   |
| CO <sub>2</sub>                      | Kohlendioxid  |
| COP                                  | Leistungszahl (coefficient of performance)  |
| CSB                                  | Chemischer Sauerstoffbedarf: zur Ermittlung des CSB werden die in einer Abwasserprobe enthaltenen organischen Substanzen mit dem Oxidationsmittel Kaliumdichromat bei ca. 150 °C abgebaut und die dafür erforderliche Sauerstoffmenge festgestellt.   |
| DC                                   | Trockenkondensation (dry condensing)  |

|                                |  |
|--------------------------------|--|
| DDGS                           | Feste und gelöste Stoffe aus der Destillation (distiller's dried grains with solubles)   |
| DMRI                           | Dänisches Forschungsinstitut für Fleischwirtschaft (Danish Meat Research Institute)  |
| DT                             | Desolventierer-Toaster   |
| DTPMP                          | Diethylentriamin-penta(methylenphosphonsäure)  |
| EC                             | Europäische Kommission (European Commission)   |
| ED                             | Elektrodialyse   |
| EDTE                           | Ethylendiamintetraessigsäure   |
| EGSB-Reaktor                   | Mit erweitertem Granulatschlammbett arbeitender Reaktor (expanded granular sludge blanket reactor)   |
| EIPPCB                         | Europäisches Büro für integrierte Vermeidung und Verminderung der Umweltverschmutzung  |
| EMAS                           | EG-Öko-Audit   |
| EMS                            | Umweltmanagementsystem (environmental management system)   |
| Entspannungsflotation          | Entspannungsflotation (DAF: dissolved air flotation)   |
| EP                             | Elektrofilter (electrostatic precipitator)   |
| EPA                            | US-Umweltschutzbehörde (Environmental Protection Agency)   |
| ESP                            | Elektrofilter (electrostatic precipitator)   |
| ETBPP                          | Vom britischen Umweltministerium aufgelegtes Förderprogramm zur Verbesserung der Umweltbilanz (Environmental Technology Best Practice Programme)             |
| EU                             | Europäische Union  |
| EU-15                          | A, B, D, DK, E, EL, F, FIN, I, IRL, L, NL, P, S und UK   |
| EU-25                          | A, B, CY, CZ, D, DK, E, EE, EL, F, FIN, HU, I, IRL, L, LV, LT, MT, NL, P, PL, S, SI, SK und UK   |
| EUCA                           | Europäische Vereinigung der Kaffeerösterverbände (European Coffee Association)   |
| FBD                            | Wirbelschichttrockner (fluidised bed drier)  |
| Fe                             | Eisen  |
| FeCl <sub>3</sub>              | Eisentrichlorid  |
| FFS                            | Verpackungsprozess für Lebensmittel: Thermoformung/Filmextrusion der Verpackung, Abfüllung und Versiegelung (form, fill and seal)                            |
| FKW                            | Fluorkohlenwasserstoffe  |
| FOG                            | Fette und Öle (fats, oils, greases)  |
| Freie Fettsäuren               | Freie Fettsäuren (free fatty acids)  |
| GE                             | Eine Standard-Geruchseinheit (GE) ist diejenige Menge Geruchsträger, die verteilt in 1 m <sup>3</sup> Neutralluft gerade eben eine Geruchsempfindung auslöst |
| GVO                            | Gentechnisch veränderte Organismen   |
| H <sub>2</sub> SO <sub>4</sub> | Schwefelsäure  |
| HACCP                          | Gefährdungsanalyse und kritische Kontrollpunkte (Hazard Analysis Critical Control Points).   |
| HCH                            | Hexachlorcyclohexan (Lindan). Ein Insektizid   |
| HCl                            | Chlorwasserstoffsäure (Salzsäure)  |
| HDPE                           | Polyethylen hoher Dichte (high density poly-ethylene)  |
| HEPA                           | Hochleistungspartikel(filter) (high efficiency particulate air)  |
| H-FCKW                         | Teilhalogenierte Fluorchlorkohlenwasserstoffe  |
| HHST                           | Hoherhitzung (ein Pasteurisierungsverfahren), (high heat short time).  |
| HP                             | Hochdruck (high pressure)  |
| HPLV                           | System mit hohem Druck und niedrigem Mengendurchsatz (high pressure low volume)  |
| HTD                            | Hochtemperaturtrocknung (high temperature drying)  |

|                      |   |
|----------------------|---|
| HTST                 | Kurzzeiterhitzung (ein Pasteurisierungsverfahren), HTST (high temperature short time)   |
| IC                   | Interne Zirkulation (Reaktor zur Abwasserbehandlung)  |
| ICW                  | Integrierte künstlich geschaffene Feuchtgebiete (integrated constructed wetlands)   |
| IDS                  | Iminodisuccinat   |
| IMPEL                | Netzwerk der Europäischen Union für die Durchführung und Durchsetzung des Umweltrechts (European Union Network for the Implementation and Enforcement of Environmental Law) |
| ISCST                | Ausbreitungsmodell der US-amerikanischen Umweltbehörde EPA (Industrial Source Complex Short Term)   |
| ISO                  | Internationale Organisation für Normung (International Organisation for Standardisation)  |
| IVU                  | Integrierte Vermeidung und Verminderung der Umweltverschmutzung   |
| k.A.                 | Keine Angaben   |
| Kläranlage           | Kläranlage (WWTP: waste water treatment plant)  |
| Kommunale Kläranlage | Kommunale Kläranlage (municipal waste water treatment plant)  |
| KWK                  | Kraft-Wärme-Kopplung (Kombination der Erzeugung von Wärme und Strom)  |
| LAS                  | Linear-Alkylbenzol-Sulfonat   |
| LDPE                 | Polyethylen niedriger Dichte (low density poly-ethylene)  |
| LOEC                 | Lowest Observed Effect Concentration. Die geringste Konzentration einer Testsubstanz, die eine messbare Wirkung auf den untersuchten Organismus zeigt                       |
| LP                   | Niedriger Druck (low pressure)  |
| LPG                  | Flüssiggas (liquefied petroleum gas)  |
| LTD                  | Niedertemperaturtrocknung (low temperature drying)  |
| LTDM                 | LTDM-Modell zur Charakterisierung von Geruchsbelästigungen (long-term frequency distribution model)   |
| MAP                  | MAP-Verpackung (bei der normalerweise Kohlendioxid, Sauerstoff und Stickstoff als Schutzgase eingesetzt werden) (modified atmosphere packing)                               |
| MBV                  | Mechanische Brüdenverdichtung   |
| Membranbioreaktor    | Membranbioreaktor (membrane bio-reactor)  |
| MF                   | Mikrofiltration   |
| MGDA                 | Methylglycindiacetat  |
| MLSS                 | Schlammkonzentration im belebten Schlamm (mixed liquor suspended solids)  |
| Mo                   | Molybdän  |
| MS(s)                | Mitgliedsstaat(en) der Europäischen Union   |
| n.e.c.               | Nicht anderweitig klassifiziert (not elsewhere classified)  |
| NF                   | Nanofiltration  |
| N-ges                | Gesamtstickstoff  |
| NGO                  | Regierungsunabhängige Organisation  |
| NH <sub>3</sub>      | Ammoniak  |
| NH <sub>4</sub>      | Ammonium  |
| NH <sub>4</sub> -N   | Ammoniumstickstoff  |
| NPV                  | Barwertüberschuss (net present value)   |
| NTE                  | Nitrilotriessigsäure  |
| NTU                  | Einheit zur Messung der Wassertrübung (nephelometric turbidity units)   |
| OU                   | Geruchseinheit (odour unit(s)), siehe auch GE   |
| P                    | Phosphor  |
| PAK                  | Polyzyklische aromatische Kohlenwasserstoffe  |
| PE                   | Polyethylen   |

|                               |   |
|-------------------------------|---|
| PET                           | Polyethylenterephthalat   |
| Pid                           | Prozessfluss- und Instrumentierungsdiagramme (process and instrumentation diagrams)   |
| PLC                           | Programmierbare logische Steuerung (programmable logic control)   |
| PM                            | Suspendierte Partikeln (particulate matter)   |
| PP                            | Polypropylen  |
| PS                            | Polystyrol  |
| PTA                           | Peseta  |
| PTFE                          | Polytetrafluorethylen   |
| PVC                           | Polyvinylchlorid  |
| QAC                           | Quartäre Ammoniumverbindung (quaternary ammonium compounds)   |
| RBC                           | Rotationstauchkörper (rotating biological contactor)  |
| RTD                           | Forschung, Technik und Entwicklung (research, technology and development)   |
| SBAF-Filter                   | Getauchte und belüftete Biofilter (submerged biological aerated filter)   |
| SBR                           | SBR-Anlage, sequenzielles biologisches Reinigungsverfahren (sequencing batch reactor)   |
| SEC                           | Spezifischer Energieverbrauch (specific energy consumption)   |
| SF                            | Suspendierte Feststoffe   |
| SME                           | Kleine und mittelständische Unternehmen (small and medium enterprises)  |
| SO <sub>2</sub>               | Schwefeldioxid  |
| SO <sub>3</sub>               | Schwefeltrioxid   |
| SO <sub>x</sub>               | Schwefeloxide   |
| Spezifische Schlamm-belastung | Verhältnis Nahrungsmittel/Mikroorganismen   |
| TAG                           | Technische Arbeitsgruppe  |
| TBV                           | Thermische Brüdenverdichtung  |
| TDS                           | Gelöste Stoffe insgesamt (total dissolved solids)   |
| TKN                           | Kjeldahl-Stickstoff insgesamt (total Kjeldahl nitrogen)   |
| TOC                           | Organischer Kohlenstoff insgesamt (total organic carbon).   |
| TS                            | Feststoffe insgesamt (total solids)   |
| TSE                           | Übertragbare spongiforme Enzephalopathie (transmissible spongiform encephalopathy)  |
| TSS                           | Suspendierte Feststoffe insgesamt (total suspended solids)  |
| U/min                         | Umdrehungen pro Minute  |
| UASB-Reaktor                  | Von unten durchströmter Reaktor mit anaerobem Schlammbett (upflow anaerobic sludge blanket reactor)                                 |
| UF                            | Ultrafiltration   |
| UHP                           | Ultrahochdruck  |
| UHT                           | Ultrahochtemperatur (Ultrahoherhitzung zur Sterilisation)   |
| Umkehrosmose                  | Umkehrosmose (RO: reverse osmosis)  |
| UV                            | Ultraviolett  |
| VOC                           | Flüchtige organische Verbindung(en) (volatile organic compound(s); nicht beschränkt auf die Definition in EU-Richtlinie 1999/13/EC) |
| WFE                           | Dünnschichtverdampfer (wiped film evaporator)   |
| WHB                           | Abwärmekessel (waste heat boiler)   |
| WHO                           | Weltgesundheitsorganisation (World Health Organisation)   |
| XPP                           | Schaumpolypropylen (expanded polypropylene)   |
| z. B.                         | Zum Beispiel (lateinisch <i>exempli gratia</i> )  |

## Liste der EU-Mitgliedsstaaten

| Kurzbezeichnung        | Amtlicher Name  | Ländercode |
|------------------------|---|------------|
| Belgien                | Königreich Belgien                                      | B          |
| Dänemark               | Königreich Dänemark                                     | DK         |
| Deutschland            | Bundesrepublik Deutschland                              | D          |
| Estland                | Republik Estland  | EE         |
| Finnland               | Republik Finnland                                       | FIN        |
| Frankreich             | Französische Republik                                   | F          |
| Griechenland           | Hellenische Republik                                    | EL         |
| Irland                 | Irland  | IRL        |
| Italien                | Italienische Republik                                   | I          |
| Lettland               | Republik Lettland                                       | LV         |
| Litauen                | Republik Litauen  | LT         |
| Luxemburg              | Großherzogtum Luxemburg                                 | L          |
| Malta                  | Republik Malta  | MT         |
| Niederlande            | Königreich der Niederlande                              | NL         |
| Österreich             | Republik Österreich                                     | A          |
| Polen                  | Volksrepublik Polen                                     | PL         |
| Portugal               | Portugiesische Republik                                 | P          |
| Schweden               | Königreich Schweden                                     | S          |
| Slowakei               | Slowakische Republik                                    | SK         |
| Slowenien              | Republik Slowenien                                      | SI         |
| Spanien                | Königreich Spanien                                      | E          |
| Tschechien             | Tschechische Republik                                   | CZ         |
| Ungarn                 | Ungarische Volksrepublik                                | HU         |
| Vereinigtes Königreich | Vereinigtes Königreich<br>Großbritannien und Nordirland | UK         |
| Zypern                 | Republik Zypern   | CY         |

## Währungsabkürzungen

| Abkürzung | Währung                    |
|-----------|----------------------------|
| ATS       | Österreichischer Schilling |
| BEF       | Belgischer Franc           |
| CZK       | Tschechische Krone         |
| DEM       | Deutsche Mark              |
| DKK       | Dänische Krone             |
| EEK       | Estnische Krone            |
| ESP       | Spanische Peseta           |
| EUR       | Euro                       |
| FIM       | Finnische Mark             |
| FRF       | Französischer Franc        |
| GBP       | Pfund Sterling             |
| GRD       | Griechische Drachme        |
| HUF       | Ungarischer Forint         |
| IEP       | Irishes Pfund              |
| ITL       | Italienische Lire          |
| NLG       | Holländischer Gulden       |
| PLN       | Polnischer Zloty           |
| PTE       | Portugiesischer Escudo     |
| SEK       | Schwedische Krone          |

## Einheitenzeichen

| Einheitenzeichen | Einheitenname / Erläuterung  |
|------------------|--|
| % v/v            | Abkürzung für Volumenprozent (auch Vol-%)  |
| % w/w            | Abkürzung für Gewichtsprozent (auch Gew-%)   |
| $\Omega$         | Ohm, Einheitenzeichen für den elektrischen Widerstand  |
| $\Omega$ cm      | Ohmzentimeter, Einheitenzeichen für den spezifischen elektrischen Widerstand   |
| $\mu$ m          | Einheitenzeichen für Micrometer ( $1 \mu\text{m} = 10^{-6} \text{m}$ )   |
| $\Delta$ T       | Temperaturanstieg  |
| ~                | circa, etwa  |
| $^{\circ}$ C     | Grad Celsius   |
| ACkWh            | Kilowattstunden (Wechselstrom)   |
| atm              | Physikalische Atmosphäre ( $1 \text{atm} = 101325 \text{N/m}^2$ )  |
| bar              | Bar ( $1,013 \text{bar} = 1 \text{atm}$ )  |
| bar (g)          | Relativer Druck bar (g) = absoluter Druck bar (a) + 1,01 bar (atmosphärischer Druck).  |
| Billion          | Eine Million Millionen ( $10^{12}$ )   |
| CGS-System       | Grundeinheiten: Zentimeter, Gramm, Sekunde. Einheitensystem, das inzwischen weitgehend vom SI-System abgelöst wurde  |
| cm               | Zentimeter   |
| cSt              | Einheit für die kinematische Viskosität, 1 Centistoke = $10^{-2}$ Stokes   |
| d                | Einheitenzeichen für Tag   |
| dB               | Dezibel. Einheitenzeichen für Schalldruckpegel   |
| dB(A)            | Der Schalldruckpegel wird in Dezibel (dB) gemessen. Bei der Bestimmung des Schalldruckpegels wird bei der technischen Messvorrichtung ein Filter (A) vorgeschaltet, der die anatomischen Eigenschaften des menschlichen Ohres nachempfinden soll. Der so gemessene und bewertete Schalldruckpegel wird mit der logarithmischen Einheit dB(A) wiedergegeben. Jede Absenkung um 3 dB(A) entspricht einer Halbierung des Schalldruckpegels. |
| eV               | Einheitenzeichen für Elektronenvolt  |
| g                | Einheitenzeichen für Gramm   |
| GE               | Abkürzung für eine Geruchseinheit (GE) <sup>43</sup> . Eine GE/m <sup>3</sup> ist zugleich der Skalenfixpunkt für die Geruchsstoffkonzentration (cG).  |
| Gew.-%           | Abkürzung für Gewichtsprozent (auch % w/w)   |
| GJ               | Einheitenzeichen für Gigajoule   |
| h                | Einheitenzeichen für Stunde  |
| ha               | Einheitenzeichen für Hektar ( $100 \times 100 \text{m} = 10.000 \text{m}^2$ ).   |
| hl               | Einheitenzeichen für Hektoliter ( $1 \text{hl} = 100 \text{l}$ )   |
| hPa              | Einheitenzeichen für Hektopascal ( $1 \text{hPa} = 100 \text{Pa}$ )  |
| Hz               | Einheitenzeichen für Hertz   |
| J                | Einheitenzeichen für Joule   |
| K                | Einheitenzeichen für Kelvin ( $0^{\circ}\text{C} = 273,15 \text{K}$ )  |
| kA               | Einheitenzeichen für Kiloampere  |
| kcal             | Einheitenzeichen für Kilokalorie ( $1 \text{kcal} = 4,19 \text{kJ}$ )  |
| kg               | Einheitenzeichen für Kilogramm ( $1 \text{kg} = 1000 \text{g}$ )   |
| kJ               | Einheitenzeichen für Kilojoule ( $1 \text{kJ} = 0,24 \text{kcal}$ )  |
| kPa              | Einheitenzeichen für Kilopascal  |

<sup>43</sup> Anm. d. UBA-Bearb.: Ist nach VDI 3882 diejenige Menge (Teilchenzahl) Geruchsträger, die verteilt in 1 m<sup>3</sup> Neutralluft - entsprechend der Definition der Geruchsschwelle- bei 50 % der Versuchspersonen (Probanden) gerade eine Geruchsempfindung auslöst. Eine GE/m<sup>3</sup> ist zugleich der Skalenfixpunkt für die Geruchsstoffkonzentration (cG).  
Geruchsschwelle: Die niedrigste Konzentration, bei der ein Geruch wahrgenommen wird, wird als Geruchsschwelle in der Einheit des Konzentrationsmaßes, z. B.  $\mu\text{g}/\text{m}^3$  oder  $\text{mg}/\text{m}^3$ , bezeichnet. Konzentrationsvielfache der Geruchsschwellen werden als Geruchseinheiten bezeichnet.

| Einheitenzeichen     | Einheitenname / Erläuterung  |
|----------------------|--|
| kt                   | Einheitenzeichen für Kilotonne   |
| kW                   | Einheitenzeichen für Kilowatt  |
| kW <sub>e</sub>      | Einheitenzeichen für Kilowatt (in Form von elektrischer Energie)   |
| kWh                  | Einheitenzeichen für Kilowattstunde (1 kWh = 3600 kJ = 3,6 MJ = 0,0036 GJ)   |
| kWh <sub>e</sub>     | Einheitenzeichen für Kilowattstunde (in Form von elektrischer Energie)   |
| l                    | Einheitenzeichen für Liter   |
| m                    | Einheitenzeichen für Meter   |
| m/min                | Meter pro Minute   |
| m <sup>2</sup>       | Einheitenzeichen für Quadratmeter  |
| m <sup>2</sup> ·°C/W | Einheitenzeichen für Wärmewiderstand   |
| m <sup>3</sup>       | Einheitenzeichen für Kubikmeter  |
| mg                   | Einheitenzeichen für Milligramm (1 mg = 10 <sup>-3</sup> g)  |
| MJ                   | Einheitenzeichen für Megajoule (1 MJ = 1.000 kJ = 10 <sup>6</sup> J)   |
| mm                   | Einheitenzeichen für Millimeter (1 mm = 10 <sup>-3</sup> m)  |
| mmWG                 | Wasserstandsanzeige mit mm-Teilung (millimetre water gauge)  |
| Mrd.                 | Milliarde, tausend Millionen (10 <sup>9</sup> )  |
| Mt                   | Einheitenzeichen für Megatonne (1 Mt = 10 <sup>6</sup> t)  |
| Mt/Jahr              | Megatonnen pro Jahr  |
| mV                   | Einheitenzeichen für Millivolt   |
| MW <sub>e</sub>      | Einheitenzeichen für Megawatt (in Form von elektrischer Energie)   |
| MW <sub>th</sub>     | Einheitenzeichen für Megawatt (in Form von Wärmeenergie)   |
| ng                   | Einheitenzeichen für Nanogramm (1 ng = 10 <sup>-9</sup> g)   |
| nm                   | Einheitenzeichen für Nanometer (1 nm = 10 <sup>-9</sup> m)   |
| Nm <sup>3</sup>      | Einheitenzeichen für Normal-Kubikmeter (bei 0 °C und 1 bar)  |
| °C/W                 | Einheitenzeichen für Wärmewiderstand   |
| Pa                   | Einheitenzeichen für Pascal  |
| ppb                  | Teile pro Milliarde  |
| ppm                  | Teile pro Million (Gewicht)  |
| ppmv                 | Teile pro Million (Volumen)  |
| s                    | Einheitenzeichen für Sekunde   |
| S (S/m oder mS/cm)   | Siemens, Einheitenzeichen für die spezifische elektrische Leitfähigkeit (Siemens pro Meter oder Millisiemens pro Zentimeter)                         |
| sq ft                | Einheitenzeichen für Quadratfuß (= 0,092 m <sup>2</sup> )  |
| St                   | Einheitenzeichen für Stokes. Nicht mehr gebräuchliche Einheit des CGS-Systems für kinematische Viskosität. 1 St = 10 <sup>-6</sup> m <sup>2</sup> /s |
| t                    | Einheitenzeichen für metrische Tonne (1000 kg oder 10 <sup>6</sup> g)  |
| t/Jahr               | Tonne(n) pro Jahr  |
| t/Tag                | Tonnen pro Tag   |
| TJ                   | Einheitenzeichen für Terajoule (1TJ = 10 <sup>6</sup> MJ = 10 <sup>9</sup> kJ= 10 <sup>12</sup> J)   |
| V                    | Einheitenzeichen für Volt  |
| Vol-%                | Abkürzung für Volumenprozent (auch % v/v)  |
| W                    | Einheitenzeichen für Watt (1 W = 1 J/s)  |
| yr                   | Jahr   |