EUROPEAN COMMISSION

Integrated Pollution Prevention and Control (IPPC)

Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs

July 2003

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

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

EXECUTIVE SUMMARY

The Intensive Rearing of Poultry and Pigs (ILF) BREF (Best Available Techniques reference document) reflects an information exchange carried out under Article 16(2) of Council Directive 96/61/EC. This executive summary – which is intended to be read in conjunction with the BREF Preface's explanation of objectives, usage and legal terms – describes the main findings, the principal BAT conclusions and the associated emission/consumption levels. It can be read and understood as a stand-alone document but, as a summary, it does not present all the complexities of the full BREF text. It is therefore not intended as a substitute for the full BREF text as a tool in BAT decision making.

Scope of work

The scope of the BREF for intensive livestock is based on Section 6.6 of Annex I of the IPPC Directive 96/61/EC as 'Installations for the intensive rearing of poultry or pigs with more than:

(a) 40000 places for poultry
(b) 2000 places for production pigs (over 30 kg), or
(c) 750 places for sows.'

The Directive does not define the term 'poultry'. From the discussion in the Technical Working Group (TWG) it was concluded that in this document the scope of poultry is chicken laying hens and broilers, turkeys, ducks and Guinea fowls. However, only laying hens and broilers are considered in detail in this document because of a lack of information on turkeys, ducks and Guinea fowls. The production of pigs includes the rearing of weaners, whose growing/finishing starts at a weight that varies between 25 and 35 kg of live weight. The rearing of sows includes mating, gestating and farrowing sows and gilts.

Structure of the industry

Farming in general

Farming has been and still is dominated by family run businesses. Until the sixties and into the early seventies, poultry and pig production were only part of the activities of a mixed farm, where crops were grown and different animal species were kept. Feed was grown on the farm or purchased locally and residues of the animal were returned to the land as fertiliser. Only a very small number of this type of farm may still exist in the EU, because increasing market demands, the development of genetic material and farming equipment and the availability of relatively cheap feed has encouraged farmers to specialise. As a consequence animal numbers and farm sizes have increased and intensive livestock farming began.

Animal welfare issues and developments in these have been respected throughout this work, although they have not been a primary driving force. In addition to the existing EU-legislation, the discussion about animal welfare will be continued. Some of the Member States have already different regulations concerning animal welfare and promote housing system requirements exceeding animal welfare regulations.

Poultry

Worldwide, Europe is the second largest producer of hen eggs with about 19 % of the world total and it is expected that this production will not change significantly in the coming years. Eggs for human consumption are produced in all Member States. The largest producer of eggs in the EU is France (17 % of egg production) followed by Germany (16 %), Italy and Spain (both 14 %) closely followed by the Netherlands (13 %). Of the exporting Member States the Netherlands is the largest exporter with 65 % of its production exported, followed by France, Italy and Spain, while in Germany consumption is higher than production. Most of the EU-produced consumption eggs (about 95 %) are consumed within the European community itself.

The majority of laying hens in the EU are kept in cages, although particularly in Northern Europe, non-cage egg production has gained in popularity over the past ten years. For example, the United Kingdom, France, Austria, Sweden, Denmark and the Netherlands have all increased the proportion of eggs produced in systems such as barn, semi-intensive, free range and deep litter. Deep litter is the most popular non-cage system in all Member States, except for France, Ireland and the United Kingdom, where semi-intensive systems and free range are preferred.

The number of layers kept on one farm varies considerably between a few thousand and up to several hundred thousand. Only a relatively small number of farms per Member State are expected to be under the scope of the IPPC Directive, i.e. over 40000 laying hens. The total number of farms in the EU meeting this threshold is just over 2000.

The biggest producer of poultry meat in the EU-15 (year 2000) is France (26 % of EU-15 poultry meat production), followed by United Kingdom (17 %), Italy (12 %) and Spain (11 %). Some countries are clearly export-orientated, such as the Netherlands, where 63 % of production is not consumed within the country, and Denmark, France and Belgium where 51 %, 51 % and 31 % of production are not consumed within the country of production. On the other hand, some countries such as Germany, Greece and Austria have consumption higher than production; in those countries, 41 %, 21 % and 23 % of the total consumption is imported from other countries.

Production of poultry meat has been increasing since 1991. The largest EU producers (France, UK, Italy and Spain) all show an increase in their poultry meat production.

Broilers are generally not housed in cages, although cage systems exist. The majority of poultry meat production is based on an all-in all-out system applying littered floors. Broiler farms with over 40000 bird places, thus falling under the scope of the IPPC Directive, are quite common in Europe.

Pigs

The EU-15 accounts for approximately 20 % of world pork production, which is indicated by slaughtered carcass weight. The major producer of pork is Germany (20 %), followed by Spain (17 %), France (13 %), Denmark (11 %) and the Netherlands (11 %). Together they produce more than 70 % of the EU-15 indigenous production. The EU-15 is a net exporter of pork, importing only a very small amount. However, not every major producer is a net exporter; Germany, for example, imported about twice as much as it exported in 1999.

In the EU-15, pig production increased by 15 % between 1997 and 2000. The total number of pigs in December 2000 was 122.9 million, which corresponds to a 1.2 % decrease as compared with 1999.

Pig farms vary considerably in size. Across the EU-15, 67 % of sows are in units of more than 100 sows. In Belgium, Denmark, France, Ireland, Italy, the Netherlands and the United Kingdom this figure is over 70 %. In Austria, Finland and Portugal smaller sow units are predominant.

The majority of pigs for fattening (81 %) are reared on units of 200 pigs or more, with 63 % of them on units of more than 400 pigs. 31 % of fattening pigs are reared on holdings of more than 1000 pigs. The industry in Italy, United Kingdom and Ireland is characterised by units of more than 1000 fattening pigs. Germany, Spain, France and the Netherlands have significant proportions of pigs in units of between 50 and 400 fattening pigs. From these numbers it is obvious that only a relatively small number of farms will fall under the scope of the IPPC Directive.

In the assessment of consumption and emission levels of pig farming it is important to know the production system applied. Growing and finishing typically aim for a slaughter weight of 90 - 95 kg (UK), 100 – 110 kg (other) or 150 – 170 kg (Italy), these weights being reached over different periods of time.

Environmental impact of the industry

In intensive livestock the key environmental aspect is that the animals metabolise feed and excrete nearly all the nutrients via manure. In the production of pigs for slaughter the process of nitrogen consumption, utilisation and losses is well understood and is shown in Figure 1. Unfortunately such a figure is not available for poultry.

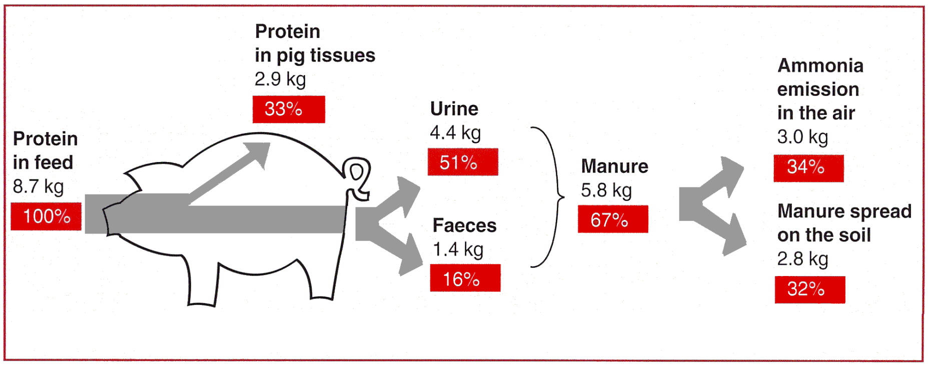

Figure 1: Consumption, utilisation and losses of protein in the production of a pig of 108 kg

Intensive livestock farming coincides with high animal densities and this density can be considered as a rough indicator of the amount of animal manure produced by the livestock. A high density might suggest that the mineral supply available from the animal manure might exceed the requirements of the agricultural area for growing crops or maintaining grassland.

In most countries pig production is concentrated in certain regions, for example in the Netherlands production is concentrated in the southern provinces, in Belgium it is strongly concentrated in West Flanders. In France intensive pig production is concentrated in Brittany and in Germany pig production is concentrated in the northwest. Italy has concentrations of pig production in the Po valley; in Spain this is in Cataluña and Galicia and in Portugal pig production is concentrated in the north. The highest densities are reported to be in the Netherlands, Belgium and Denmark.

Data on the concentration of livestock production at a regional level are considered to be a good indication of whether a region might have potential environmental problems. This is clearly illustrated by Figure 2, which shows problems such as: acidification (NH_3, SO_2, NO_x), eutrophication (N, P), local disturbance (odour, noise) and diffuse spreading of heavy metals and pesticides.

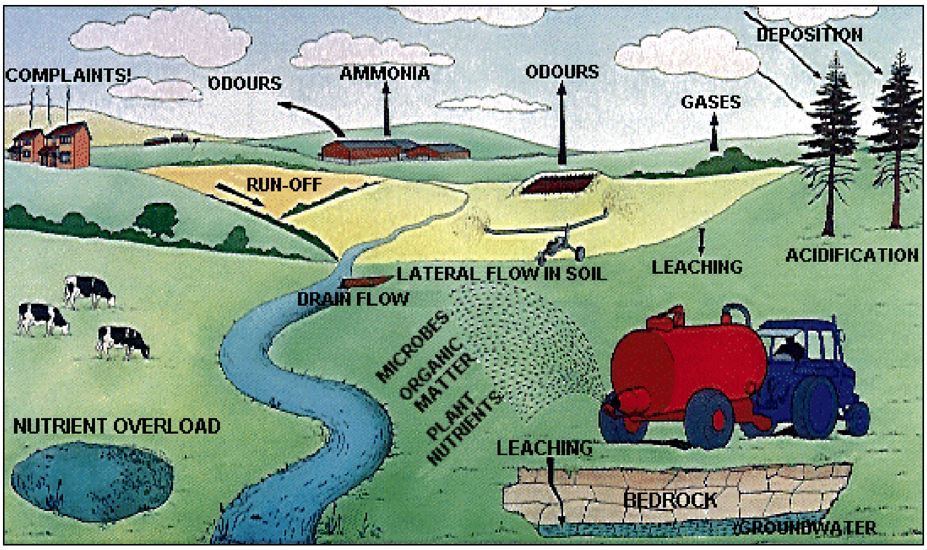

Figure 2: Illustration of environmental aspects related to intensive livestock farming

Applied techniques and BAT on intensive livestock farming

Generally, the activities that can be found on intensive livestock farms are:

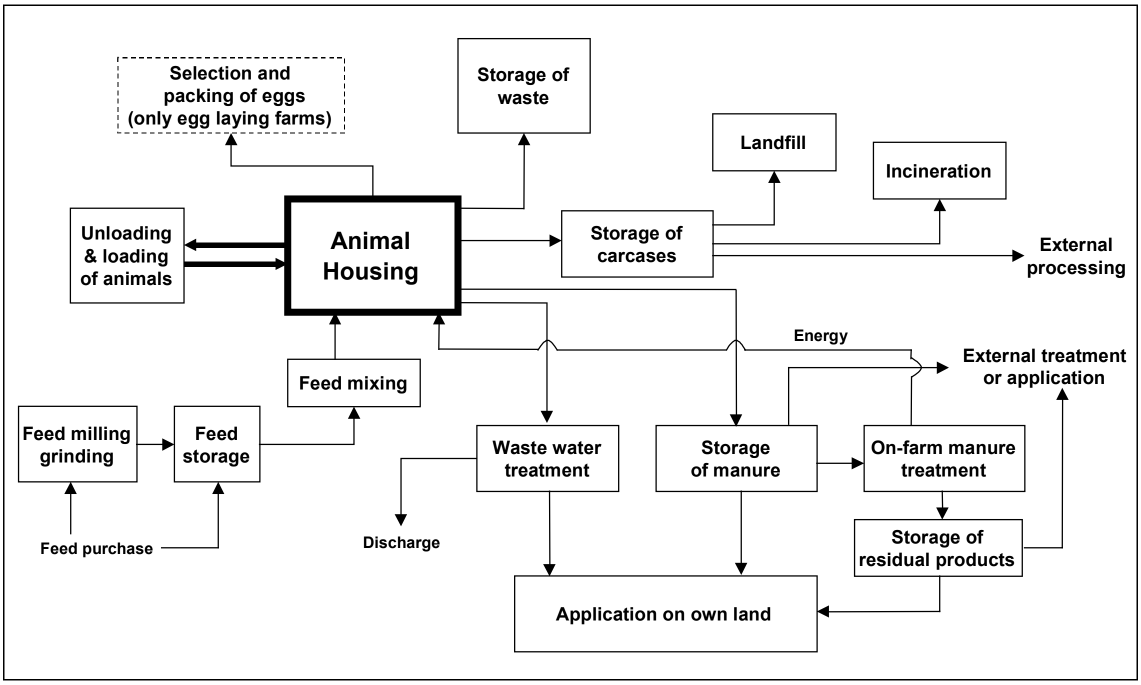

Figure 3: General scheme of activities on intensive livestock farms

The central environmental issue in intensive livestock farming is manure. This is reflected in the order in which on-farm activities are presented in Chapters 4 and 5 in this document, starting with good agricultural practice, followed by feeding strategies to influence quality and composition of the manure, methods of removing the manure from the housing system, the storage and treatment of manure and finally the landspreading of manure. Other environmental issues such as waste, energy, water and waste water, and noise are also addressed, although in lesser detail.

Ammonia has been given most attention as the key air pollutant as it is emitted in the highest quantities. Nearly all the information on the reduction of emissions from animal housing reported on the emission reduction of ammonia. It is assumed that techniques reducing the emissions of ammonia will reduce emissions of the other gaseous substances as well. Other environmental impacts relate to nitrogen and phosphorus emissions to soil, surface water and groundwater, and result from the application of manure to land. Measures to decrease these emissions are not limited to how to store, treat or apply the manure once it arises, but comprise measures throughout a whole chain of events, including steps to minimise the production of manure.

In the paragraphs below the applied techniques and the conclusions on BAT are summarised for poultry and pigs.

Good agricultural practice in the intensive rearing of pigs and poultry

Good agricultural practice is an essential part of BAT. Although it is difficult to quantify environmental benefits in terms of emission reductions or reductions in the use of energy and water, it is clear that conscientious farm management will contribute to an improved environmental performance of an intensive poultry or pig farm. For improving the general environmental performance of an intensive livestock farm, BAT is to do all of the following:

- identify and implement education and training programmes for farm staff
- keep records of water and energy usage, amounts of livestock feed, waste arising and field applications of inorganic fertiliser and manure
- have an emergency procedure to deal with unplanned emissions and incidents
- implement a repair and maintenance programme to ensure that structures and equipment are in good working order and that facilities are kept clean
- plan activities at the site properly, such as the delivery of materials and the removal of products and waste, and
- plan the application of manure to land properly.

Feeding strategies for poultry and pigs

The composition of poultry feed varies considerably not just between installations but also between MSs. This is because it is a mixture of different ingredients, such as cereals, seeds, soya beans, and bulbs, tubers, roots or root crops and products of animal origin (e.g. fish meal, meat and bone meal and milk products). The main ingredients for pigs are cereals and soya.

The efficient feeding of animals aims to supply the required amount of net energy, essential amino acids, minerals, trace elements and vitamins for growth, fattening or reproduction. Pigs feed formulation is a complex matter and factors such as, live weight and the stage of reproduction, influence the composition of feed. Liquid feed is the most commonly applied, but dry feed or mixtures are also applied.

Apart from formulating the feed to closely match the requirements of the birds and the pigs, different types of feeding are also given during production cycles. See Table 1 for the different categories and the number of feeds phases that are most commonly applied and that are BAT.

An applied technique to reduce the excretion of nutrients (N and P) in manure, for pigs and poultry, is ‘nutritional management’. Nutritional management aims to match feeds more closely to animal requirements at various production stages, thus reducing the amount of nitrogen waste rising from undigested or catabolised nitrogen, and which is subsequently eliminated through urine. Feeding measures include phase-feeding, formulating diets based on digestible/available nutrients, using low protein amino acid-supplemented diets and using low phosphorus phytase-supplemented diets or diets with highly digestible inorganic feed phosphates. Furthermore the use of certain feed additives, such as enzymes, may increase the feed efficiency thereby improving the nutrient retention and hence reducing the amount of nutrient left over in the manure.

For pigs a crude protein reduction of 2 to 3 % (20 to 30 g/kg of feed) can be achieved depending on the breed/genotype and the actual starting point, for poultry this is 1 to 2 % (10 to 20 g/kg of feed). The resulting range of dietary crude protein contents concluded to be BAT is reported in Table 1. The values in the table are only indicative, because they, amongst others, depend on the energy content of the feed. Therefore levels may need to be adapted to local conditions. Research on further applied nutrition is currently being carried out in a number of Member States and may support possible further reductions in the future, depending on the effects of changes in genotypes.

As far as phosphorus is concerned, a basis for BAT is to feed animals (poultry and pigs) with successive diets (phase-feeding) with lower total phosphorus contents. In these diets, highly digestible inorganic feed phosphates and/or phytase must be used in order to guarantee a sufficient supply of digestible phosphorus.

For poultry a total phosphorus reduction of 0.05 to 0.1 % (0.5 to 1 g/kg of feed) can be achieved depending on the breed/genotypes, the use of feed raw materials and the actual starting point by the application of highly digestible inorganic feed phosphates and/or phytase in the feed. For pigs this reduction is 0.03 to 0.07 % (0.3 to 0.7 g/kg of feed). The resulting range of dietary total phosphorus contents is reported in Table 1. As for the pigs situation, the BAT associated values in the table are only indicative, because they, amongst others, depend on the energy content of the feed. Therefore levels may need to be adapted to local conditions. Further applied nutrition research is currently being carried out in a number of Member States and may support further possible reductions in the future, depending on the effects of changes in genotypes.

Species	Phases	Crude protein content (% in feed) [1)]	Total phosphorus content (% in feed) [2)]	Remark
Broiler	starter	20 – 22	0.65 – 0.75	1) With adequately balanced and optimal digestible amino acid supply and 2) With adequate digestible phosphorus by using e.g. highly digestible inorganic feed phosphates and/or phytase
	grower	19 – 21	0.60 – 0.70	
	finisher	18 – 20	0.57 – 0.67	
Turkey	<4 weeks	24 – 27	1.00 – 1.10	
	5 – 8 weeks	22 – 24	0.95 – 1.05	
	9 – 12 weeks	19 – 21	0.85 – 0.95	
	13+ weeks	16 – 19	0.80 – 0.90	
	16+ weeks	14 – 17	0.75 – 0.85	
Layer	18 – 40 weeks	15.5 – 16.5	0.45 – 0.55	
	40+ weeks	14.5 – 15.5	0.41 – 0.51	
Weaner	<10 kg	19 – 21	0.75 – 0.85	
Piglet	<25 kg	17.5 – 19.5	0.60 – 0.70	
Fattening pig	25 – 50 kg	15 – 17	0.45 – 0.55	
	50 – 110 kg	14 – 15	0.38 – 0.49	
Sow	gestation	13 – 15	0.43 – 0.51	
	lactation	16 – 17	0.57 – 0.65	

Table 1: Indicative crude protein levels in BAT-feeds for poultry and pigs

Housing systems for poultry; laying hens

Most laying hens are still kept in cages. The conventional housing system is a battery with open manure storage under the cages, but nowadays most techniques are an improvement of this system. The principle behind the reduction of ammonia emissions from the cages is a frequent removal of the manure. Drying of manure also reduces the emissions by inhibiting the chemical reactions. The quicker the manure is dried the lower the emission of ammonia. A combination of frequent removal and forced drying of manure gives the highest reduction of ammonia emissions from the housing and also reduces emissions from the storage facilities, but at an associated energy cost. The cage systems commonly applied, and which are BAT are:

- a cage system with manure removal, at least twice a week, by way of manure belts to a closed storage
- vertical tiered cages with a manure belt and with forced air drying, where the manure is removed at least once a week to a covered storage
- vertical tiered cages with a manure belt and with whisk-forced air drying, where the manure is removed at least once a week to a covered storage
- vertical tiered cages with a manure belt and with improved forced air drying, where the manure is removed from the house at least once a week to a covered storage
- vertical tiered cages with a manure belt and with drying tunnel over the cages; the manure is removed to a covered storage after 24 – 36 hours.

The cage system with an aerated open manure storage (also known as a deep pit system) is a conditional BAT. In regions where a Mediterranean climate prevails, this system is BAT. In regions with much lower average temperatures, this technique can show a significantly higher ammonia emission and is not BAT unless a means of drying the manure in the pit is provided.

However, as a consequence of the requirements of Directive 1999/74/EC laying down minimum standards for the protection of laying hens, the above-mentioned cage systems will be banned. This will prohibit the installation of any new conventional cage systems by 2003 and lead to a total ban on the use of such cage systems by 2012. However, in 2005 it will be decided whether the above-mentioned Directive needs to be reviewed. This decision depends on the results of several studies and on-going negotiations.

The banning of conventional cage systems will require farmers to use the so-called enriched cage or non-cage systems. Different techniques applying the enriched cage concept are currently under development but little information is yet available. However, these designs will form the only alternative cage system that will be allowed for new installations from 2003 onwards. Applied non-cage housing systems, which are concluded to be BAT, are:

- a deep litter system (with or without forced drying of the manure)
- a deep litter system with a perforated floor and forced drying of the manure
- an aviary system with or without range and/or outside scratching area.

The information in the main body of the BREF, on all the above mentioned housing systems, shows that improving the animal welfare would have a negative effect of limiting the achievable reduction of ammonia emissions from layer housing.

Housing systems for poultry; broilers

The traditional housing for intensive broiler production is a simple closed building construction of concrete or wood with natural light or windowless with a light system, thermally insulated and force-ventilated. Buildings are also used that are constructed with open sidewalls (windows with jalousie-type curtains); forced ventilation (negative pressure principle) is applied by way of fans and air inlet valves. The broilers are kept on litter (normally chopped straw, but wood shavings or shredded paper are also applied) spread over the entire house floor area. Manure is removed at the end of each growing period. Broilers are normally kept at a stocking density of 18 to 24 birds per m^2 and the houses can stock between 20000 and 40000 birds. New legislation on animal welfare is expected to limit the stocking density of broilers.

To reduce ammonia emissions from the housing wet litter must be avoided. For this reason a new housing technique (VEA-system) was designed where attention was paid to the insulation of the building, to the drinking system (to avoid spillage) and to the application of wood shavings/sawdust. However, emissions were shown to be equal to the traditional housing system. The decision on BAT was that BAT on housing systems for broilers is:

- the naturally ventilated house with a fully littered floor and equipped with non-leaking drinking systems
- the well-insulated fan ventilated house with a fully littered floor and equipped with non-leaking drinking systems (VEA-system).

Some newly developed systems have a forced drying system that blows air through a layer of litter and droppings. The reduction in ammonia emissions is considerable (83 – 94 % reductions compared to the traditional housing system), but they are expensive, show an increase in energy use and have high dust levels. However, when already in place they are concluded to be BAT. These techniques are:

- a perforated floor system with forced air drying system
- a tiered floor with forced air drying system
- a tiered cage system with removable cage sides and the forced drying of manure.

There is normally a system for heating the air in broiler houses. This can be the “combideck system”, which heats the floor and the substances (such as litter) on top of it. The system consists of a heat pump, an underground storage facility made of tubes, and a layer of isolated hollow strips (intermediately spaced every 4 cm) 2 – 4 metres below the floor. The system uses two water cycles: one serving the house and the other acting as the underground storage. Both cycles are closed and connected through a heat pump. In the broiler house, the hollow strips are put in an insulated layer below the concrete floor (10 - 12 cm). Depending on the temperature of the water that flows through the strips, the floor and the litter will either be warmed up or cooled down.

This combideck system, also proposed as a technique to reduce energy, is a conditional BAT. It can be applied if local conditions allow, e.g. if soil conditions allow the installation of closed underground storages of the circulated water. The system is only applied in the Netherlands and in Germany, at a depth of 2 – 4 metres. It is not yet known if this system performs equally well in locations where the frosts are longer and harder and penetrate the soil or where the climate is much warmer and the cooling capacity of the soil might not be sufficient.

Housing systems for pigs; general remarks

A number of general points are made on pig housing which are followed by a detailed description of applied housing techniques and BAT on housings for mating and gestating sows, growers/finishers, farrowing sows and weaners.

Designs to reduce ammonia emissions to air from pig housing systems, as presented in Chapter 4, basically involve some or all of the following principles:

- reducing emitting manure surfaces
- removing the manure (slurry) from the pit to an external slurry store
- applying an additional treatment, such as aeration, to obtain flushing liquid
- cooling the manure surface
- using surfaces (for example, of slats and manure channels) which are smooth and easy to clean.

Concrete, iron and plastic are used in the construction of slatted floors. Generally speaking and given the same slat width, manure dropped on concrete slats takes longer to fall into the pit than when using iron or plastic slats, and this is associated with higher emissions of ammonia. It is worth noting that iron slats are not allowed in some Member States.

The frequent removal of manure by flushing with slurry may result in a peak in odour emissions with each flush. Flushing is normally done twice a day; once in the morning and once in the evening. These peaks in odour emissions can cause a nuisance to neighbours. Additionally treatment of the slurry also requires energy. These cross-media effects have been taken into account in defining BAT on the various housing designs.

With respect to litter (typically straw), it is expected that the use of litter in pig housing will increase throughout the Community due to a raised awareness of animal welfare. Litter may be applied in conjunction with (automatically-controlled) naturally ventilated housing systems, where litter would protect the animals from low temperatures, thus requiring less energy input for ventilation and heating. In systems where litter is used, the pen can be divided into a dunging area (without litter) and a littered solid floor area. It is reported that pigs do not always use these areas in the correct way, i.e. they dung in the littered area and/or use the slatted- or solid dunging area to lie on. However, the pen design can influence the behaviour of the pigs, although it is reported that in regions with a warm climate this might not be sufficient to prevent the pigs dunging and lying in the wrong areas. The argument for this is that in a full litter system the pigs do not have the possibility of cooling down by lying on an uncovered floor.

An integrated evaluation of litter use would include the extra costs for litter supply and mucking out, as well as the possible consequences on the emissions from storage of the manure and for the application onto land. The use of litter results in solid manure which increases the organic matter of the soils. In some circumstances therefore this type of manure is beneficial to soil quality; this is a very positive cross-media effect.

In Chapter 4 applied housing techniques for pigs are assessed on the ammonia emission reduction potential, N_2O and CH_4 emissions, cross-media effects (use of energy and water, odour, noise, dust), applicability, operability, animal welfare and cost; all compared against a specific reference system.

Housing systems for pigs; mating/gestating sows

Currently applied housing systems for mating/gestating sows are:

- fully-slatted floors, artificial ventilation and underlying deep collection pit (Note: this is the reference system)
- fully- or partly-slatted floors with a vacuum system underneath for frequent slurry removal
- fully- or partly-slatted floors with flush canals underneath the floor and where flushing is done with fresh slurry or with slurry that is aerated
- fully- or partly-slatted floors with flush gutters/tubes underneath and where flushing is done with fresh slurry or with slurry that is aerated
- partly-slatted floors with a reduced manure pit underneath
- partly-slatted floors with manure surface cooling fins
- partly-slatted floors with a manure scraper
- solid concrete floor with full litter
- solid concrete floor with straw and electronic feeders.

Currently mating and gestating sows can be housed either individually or in a group. However, EU legislation on pig welfare (91/630/EEC) provides minimum standards for the protection of pigs and will require sows and gilts to be kept in groups, from 4 weeks after service to 1 week before the expected time of farrowing, for new or rebuilt houses from 1 January 2003, and from 1 January 2013 for existing housing.

Group-housing systems require different feeding systems (e.g. electronic sow feeders) to individual housing systems, as well as a pen design that influences sow behaviour (i.e. the use of dunging- and lying areas). However, from an environmental point of view, the submitted data seems to indicate that group-housing systems have similar emission levels to individual housing systems, if similar emission reduction techniques are applied.

In the same EU legislation on pig welfare as mentioned above (Council Directive 2001/88/EC amending 91/630/EEC), requirements for flooring surfaces are included. For gilts and pregnant sows, a specified part of the floor area must be continuous solid floor of which a maximum of 15 % is reserved for drainage openings. These new provisions apply to all newly built or rebuilt holdings from 1 January 2003, and to all holdings from 1 January 2013. The effect of these new flooring arrangements on emissions compared to a typical existing fully slatted floor (which is the reference system) has not been investigated. The maximum 15 % void for drainage in the continuous solid floor area is less than the 20 % void for the concrete slatted floor area in the new provisions (a maximum 20 mm gap and a minimum slat width of 80 mm for sows and gilts). Therefore the overall effect is to reduce the void area.

In the assessment on BAT on housing systems, techniques are compared against the reference system used for the housing of mating and gestating sows, which is a deep pit under a fully-slatted floor with concrete slats. The slurry is removed at frequent or infrequent intervals. Artificial ventilation removes gaseous components emitted by the stored slurry manure. The system has been applied commonly throughout Europe. Regarding housing systems for mating/gestating sows, BAT is to have:

- fully- or partly-slatted floors with a vacuum system underneath for frequent slurry removal, or
- partly-slatted floors and a reduced manure pit.

It is generally accepted that concrete slats give more ammonia emissions than metal or plastic slats. However, for the BAT mentioned above no information was available on the effect of different slats on the emissions or costs.

New to build housing systems with a fully- or partly-slatted floor and flush gutters or tubes underneath and flushing is applied with non-aerated liquid are conditional BAT. In instances where the peak in odour, due to the flushing, is not expected to give nuisance to neighbours these techniques are BAT for new to build systems. In instances where this technique is already in place, it is BAT (without condition).

A housing system with manure surface cooling fins using a closed system with heating pumps performs well but is a very costly system. Therefore manure surface cooling fins are not BAT for new to build housing systems, but when it is already in place, it is BAT. In retrofit situations this technique can be economically viable and thus can be BAT as well, but this has to be decided on a case by case basis.

Partly-slatted floor systems with a manure scraper underneath generally perform well, but the operability is difficult. Therefore a manure scraper is not BAT for new to build housing systems, but it is BAT when the technique is already in place.

Fully- or partly-slatted floor systems and flushing gutters or tubes underneath with flushing applied with non-aerated liquid is, as already mentioned earlier, BAT when it is already in place. The same technique operated with aerated liquid is not BAT for new to build housing systems because of odour peaks, energy consumption and operability. However, in instances where this technique is already in place, it is BAT.

Split view:

One Member State supports the conclusions on BAT, but in their view the following techniques are also BAT in instances where the techniques are already in place and are also BAT when an extension (by means of a new building) is planned to operate with the same system (instead of two different systems):

- fully- or partly-slatted floors with flushing of a permanent slurry layer in channels underneath with non-aerated or aerated liquid.

These systems, often applied in this Member State, can achieve a higher ammonia emission reduction than those systems previously identified as BAT or conditional BAT. The argument then is that the high cost of retrofitting existing systems by any of these BATs is not justified. When an extension is added, for example by means of a new building, to a plant already adopting these systems, implementation of BAT or conditional BAT would reduce operability by making the operator use two different systems at the same farm. Therefore, the Member State considers these systems are BAT because of their good emission reduction capability, their operability and cost considerations.

On systems using litter very variable emission reduction potentials are reported to date, and further data must be acquired to allow better guidance on what is BAT for litter based systems. However, the TWG concluded that when litter is used, along with good practices such as having enough litter, changing the litter frequently, designing the pen floor suitably, and creating functional areas, then they cannot be excluded as BAT.

Housing systems for pigs; growers/finishers

Currently applied housing systems for growers/finishers are:

- fully-slatted floors, artificial ventilation and underlying deep collection pit (Note: this is the reference system)
- fully- or partly-slatted floors with a vacuum system underneath for frequent slurry removal
- fully- or partly-slatted floors with flush canals underneath and where flushing is done with fresh slurry or with slurry that is aerated
- fully- or partly-slatted floors with flush gutters/tubes underneath and where flushing is done with fresh slurry or with slurry that is aerated
- partly-slatted floors with a reduced manure pit underneath
- partly-slatted floors with manure surface cooling fins
- partly-slatted floors with a manure scraper

- partly-slatted floors with a central convex solid floor or an inclined solid floor at the front of the pen, a manure channel with slanted side walls and a sloped manure pit
- partly-slatted floors with a reduced manure pit, including slanted walls and a vacuum system
- partly-slatted floor with fast removal of slurry and littered external alley
- partly-slatted floor with a covered box
- solid concrete floor with full litter and outdoor climate
- solid concrete floor with a littered external alley and a straw flow system.

Growers/finishers are always housed in a group and most of the systems for the group housing of sows apply here as well. In the assessment on BAT on housing systems, techniques are compared against the reference system used for the housing of growers/finishers, which is a fully-slatted floor with a deep manure pit underneath and mechanical ventilation. On housing systems for growers/finishers, BAT is:

- a fully-slatted floor with a vacuum system for frequent removal, or
- a partly-slatted floor with a reduced manure pit, including slanted walls and a vacuum system, or
- a partly-slatted floor with a central, convex solid floor or an inclined solid floor at the front of the pen, a manure gutter with slanted sidewalls and a sloped manure pit.

It is generally accepted that concrete slats give more ammonia emissions than metal or plastic slats. However, the reported emission data show only a difference of 6 %, but costs are significantly higher. Metal slats are not allowed in every Member State, and they are not suitable for very heavy pigs.

New to build housing systems with a fully- or partly-slatted floor and flush gutters or tubes underneath and where flushing is applied with non-aerated liquid are conditional BAT. In instances where the peak in odour, due to the flushing, is not expected to give nuisance to neighbours these techniques are BAT for new to build systems. In instances where this technique is already in place, it is BAT (without condition).

A housing system with manure surface cooling fins using a closed system with heating pumps performs well but is a very costly system. Therefore manure surface cooling fins are not BAT for new to build housing systems, but when it is already in place, it is BAT. In retrofit situations this technique can be economically viable and thus can be BAT as well, but this has to be decided on a case by case basis. It has to be noted that energy efficiency can be lower in situations where the heat that arises from the cooling is not used, for example because there are no weaners to be kept warm.

Partly-slatted floor systems with a manure scraper underneath generally perform well, but the operability is difficult. Therefore a manure scraper is not BAT for new to build housing systems, but it is BAT when the technique is already in place.

Fully- or partly-slatted floor systems and flushing gutters or tubes underneath with flushing applied with non-aerated liquid is, as already mentioned earlier, BAT when it is already in place. The same technique operated with aerated liquid is not BAT for new to build housing systems because of odour peaks, energy consumption and operability. However, in instances where this technique is already in place, it is BAT.

Split view:

One Member State supports the conclusions on BAT, but for the same reason and using the same arguments as mentioned earlier on the housing for mating/gestating sows, in their view the following techniques are also BAT:

- a fully- or partly-slatted floor with flushing of a permanent slurry layer in channels underneath with non-aerated or aerated liquid.

On systems using litter very variable emission reduction potentials are reported to date, and further data must be acquired to allow better guidance on what is BAT for litter based systems. However, the TWG concluded that when litter is used, along with good practices such as having enough litter, changing the litter frequently, designing the pen floor suitably, and creating functional areas, then they cannot be excluded as BAT. The following system is an example of what may be BAT:

- solid concrete floors with a littered external alley and a straw flow system.

Housing systems for pigs; farrowing sows

Currently applied housing systems for farrowing sows are:

- crates with fully-slatted floors and underlying deep collection pit (which is the reference)
- crates with fully-slatted floors and a board on a slope underneath
- crates with fully-slatted floors and a combination of a water and manure channel underneath
- crates with fully-slatted floors and a flushing system with manure gutters underneath
- crates with fully-slatted floors and manure pan underneath
- crates with fully-slatted floors and manure surface cooling fins
- crates with partly-slatted floors
- crates with partly-slatted floors and a manure scraper

Farrowing sows in Europe are generally housed in crates with iron and/or plastic slatted floors. In the majority of the houses sows are confined in their movement, with piglets walking around freely. Most houses have controlled ventilation and often a heated area for the piglets during the first few days. This system with a deep manure pit underneath is the reference system.

The difference between fully- and partly-slatted floors is not so distinct in the case of farrowing sows, where the sow is confined in its movement. In both cases dunging takes place in the same slatted area. Reduction techniques therefore focus predominantly on alterations to the manure pit.

BAT is a crate with a fully-slatted iron or plastic floor and with a:

- combination of a water and manure channel, or
- flushing system with manure gutters, or
- manure pan underneath.

A housing system with manure surface cooling fins using a closed system with heating pumps performs well but is a very costly system. Therefore manure surface cooling fins are not BAT for new to build housing systems, but when it is already in place, it is BAT. In retrofit situations this technique can be economically viable and thus can be BAT as well, but this has to be decided on a case by case basis.

Crates with a partly-slatted floor and a manure scraper underneath generally perform well, but the operability is difficult. Therefore a manure scraper is not BAT for new to build housing systems, but it is BAT when the technique is already in place.

For new installations the following techniques are <u>not</u> BAT:

- crates with a partly-slatted floor and a reduced manure pit, and
- crates with a fully-slatted floor and a board on a slope.

However, when these techniques are already in place it is BAT. It has to be noted that with the latter system flies can easily develop if no control measures are undertaken.

Data must be acquired to allow better guidance on what is BAT for litter based systems. However, the TWG concluded that when litter is used, along with good practices such as having enough litter, changing the litter frequently, and designing the pen floor suitably then they cannot be excluded as BAT.

Housing systems for pigs; weaners

Currently applied housing systems for weaners are:

- pens or flatdecks with fully-slatted floors and an underlying deep collection pit (reference)
- pens or flatdecks with fully- or partly-slatted floors and a vacuum system for frequent slurry removal
- pens or flatdecks with fully-slatted floors and a concrete sloped floor to separate faeces and urine
- pens or flatdecks with fully-slatted floors and a manure pit with scraper
- pens or flatdecks with fully-slatted floors and flush gutters/tubes underneath, where flushing is done with fresh slurry or with slurry that is aerated
- pens with partly-slatted floors; the two-climate system
- pens with partly-slatted floors and a sloped or convex solid floor
- pens with partly-slatted floors and a shallow manure pit and a channel for spoiled drinking water
- pens with partly-slatted floors with triangular iron slats and manure channel with gutters
- pens with partly-slatted floors and manure scraper
- pens with partly-slatted floors with triangular iron slats and a manure channel with sloped side wall(s)
- pens with partly-slatted floors and manure surface cooling fins
- partly-slatted floors with triangular slats and a covered box
- solid concrete floors with straw and natural ventilation.

Weaners are housed in a group in pens or flatdecks. In principle, manure removal is the same for a pen as for a flatdeck (raised pen) design. The reference system is a pen or flatdeck with a fully-slatted floor made of plastic or metal slats and a deep manure pit.

It is assumed, that in principle, reduction measures applicable to conventional weaner pens can also be applied to the flatdeck, but experiences with such a change have not been reported.

BAT is a pen:

- or flatdeck with a fully-slatted- or partly-slatted floor with a vacuum system for frequent slurry removal, or
- or flatdeck with a fully-slatted floor beneath which there is a concrete sloped floor to separate faeces and urine, or
- with a partly-slatted floor (two-climate system), or
- with a partly-slatted iron or plastic floor and a sloped or convex solid floor, or
- with a partly-slatted floor with metal or plastic slats and a shallow manure pit and channel for spoiled drinking water, or
- with a partly-slatted floor with triangular iron slats and a manure channel with sloped side walls.

New to build housing systems with a fully-slatted floor and flush gutters or tubes underneath and where flushing is applied with non-aerated liquid are conditional BAT. In instances where the peak in odour, due to the flushing, is not expected to give nuisance to neighbours these techniques are BAT for new to build systems. In instances where this technique is already in place, it is BAT (without condition).

A housing system with manure surface cooling fins using a closed system with heating pumps performs well but is a very costly system. Therefore manure surface cooling fins are not BAT for new to build housing systems, but when it is already in place, it is BAT. In retrofit situations this technique can be economically viable and thus can be BAT as well, but this has to be decided on a case by case basis.

Fully-slatted and partly-slatted floor systems with a manure scraper generally perform well, but the operability is difficult. Therefore a manure scraper is not BAT for new to build housing systems, but it is BAT when the technique is already in place.

Weaners are also kept on solid concrete floors with part- or full litter. No ammonia emission data is reported for these systems. However, the TWG concluded that when litter is used, along with good practices such as, having enough litter, changing the litter frequently, and designing the pen floor suitably, then they cannot be excluded as BAT.

The following system is an example of what is BAT:

- a natural ventilated pen with a fully littered floor.

Water for pigs and poultry

In the rearing of pigs and poultry water is used for cleaning activities and for watering the animals. Reduction of the animals' water consumption is not considered to be practical. It will vary in accordance with their diet and, although some production strategies include restricted water access, permanent access to water is generally considered to be an obligation.

In principle three types of animal drinking systems are applied: low capacity nipple drinkers or high capacity drinkers with a drip-cup, water troughs and round drinkers for poultry, and for pigs these are: nipple drinkers in a trough or cup, water troughs and biting nipples. All of these have some advantages and some disadvantages. However, there is not enough data available to come to a BAT conclusion.

On activities where water is used, it is BAT to reduce water use by doing all of the following:

- cleaning animal housing and equipment with high-pressure cleaners after each production cycle or each batch. For pig housing, typically wash-down water enters the slurry system and therefore it is important to find a balance between cleanliness and using as little water as possible. In poultry housing it is also important to find the balance between cleanliness and using as little water as possible
- carry out a regular calibration of the drinking-water installation to avoid spill
- keeping record of water use through metering of consumption, and
- detecting and repairing leakages.

Energy for pigs and poultry

In the rearing of pigs and poultry, the information on the use of energy focuses on heating and ventilating the housing systems.

BAT for pigs and poultry is to reduce energy use by application of good farming practice starting with animal housing design and by adequate operation and maintenance of the housing and the equipment.

There are many actions that can be taken as part of the daily routine to reduce the amount of energy required for heating and ventilation. Many of these points are mentioned in the main body of the document. Some specific BAT measures are mentioned below:

BAT for poultry housing is to reduce energy use by doing all of the following:

- insulating buildings in regions with low ambient temperatures (U-value 0.4 $W/m^2/°C$ or better)
- optimising the design of the ventilation system in each house to provide good temperature control and to achieve minimum ventilation rates in winter
- avoiding resistance in ventilation systems through frequent inspection and cleaning of ducts and fans, and
- applying low energy lighting.

BAT for pig housing is to reduce energy use by doing all of the following:

- applying natural ventilation where possible; this needs proper design of the building and of the pens (i.e. microclimate in the pens) and spatial planning with respect to the prevailing wind directions to enhance the airflow; this applies only to new housing
- for mechanically ventilated houses: optimising the design of the ventilation system in each house to provide good temperature control and to achieve minimum ventilation rates in winter
- for mechanically ventilated houses: avoiding resistance in ventilation systems through frequent inspection and cleaning of ducts and fans, and
- applying low energy lighting.

Storage of manure from pigs and poultry

The Nitrates Directive lays down minimum provisions on storage of manure in general with the aim of providing all waters a general level of protection against pollution, and additional provisions on storage of manure in designated Nitrate Vulnerable Zones. Not all provisions in this Directive are addressed in this document because of a lack of data, but where they are addressed, the TWG agreed that BAT for slurry storage tanks, solid manure heaps or slurry lagoons is equally valid inside and outside these designated Nitrate Vulnerable Zones.

BAT is to design storage facilities for pig and poultry manure with sufficient capacity until further treatment or application to land can be carried out. The required capacity depends on the climate and the periods in which application to land is not possible. For pig manure, for example, the capacity can differ from the manure that is produced on a farm over a 4 – 5 month period in Mediterranean climate, a 7 – 8 month period in the Atlantic or continental conditions, to a 9 – 12 month period in boreal areas. For poultry manure the required capacity depends on the climate and the periods in which application to land is not possible

For a stack of pig manure that is always situated on the same place, either on the installation or in the field, BAT is to:

- apply a concrete floor, with a collection system and a tank for run-off liquid, and
- locate any new to build manure storage areas where they are least likely to cause annoyance to sensitive receptors for odour, taking into account the distance to receptors and the prevailing wind direction.

If poultry manure needs to be stored, BAT is to store dried poultry manure in a barn with an impermeable floor, and with sufficient ventilation.

For a temporary stack of pig or poultry manure in the field, BAT is to position the manure heap away from sensitive receptors such as, neighbours, and watercourses (including field drains) that liquid run-off might enter.

BAT on the storage of pig slurry in a concrete or steel tank comprises all of the following:

- a stable tank able to withstand likely mechanical, thermal and chemical influences
- the base and walls of the tank are impermeable and protected against corrosion
- the store is emptied regularly for inspection and maintenance, preferably every year
- double valves are used on any valved outlet from the store
- the slurry is stirred only just before emptying the tank for, e.g., application on land.

It is BAT to cover slurry tanks using one of the following options:

- a rigid lid, roof or tent structure, or
- a floating cover, such as chopped straw, natural crust, canvas, foil, peat, light expanded clay aggregate (LECA) or expanded polystyrene (EPS).

All of these types of covers are applied but have their technical and operational limitations. This means that the decision on what type of cover is preferred can only by taken on a case by case basis.

A lagoon used for storing slurry is equally as viable as a slurry tank, providing it has impermeable base and walls (sufficient clay content or lined with plastic) in combination with leakage detection and provisions for a cover.

It is BAT to cover lagoons where slurry is stored using one of the following options:

- a plastic cover, or
- a floating cover, such as chopped straw, LECA or natural crust.

All these types of covers are applied but have their technical and operational limitations. This means that the decision on what type of cover is preferred can only by taken on a case by case basis. In some situations it might be very costly, or technically not even possible to install a cover to an existing lagoon. The cost for installing a cover for very large lagoons or lagoons that have unusual shapes can be high. It might technically be impossible to install a cover when, for example, embankment profiles are not suitable to attach the cover to.

On-farm treatment of manure from pigs and poultry

Manure treatment prior to or instead of land spreading may be performed for the following reasons:

1. to recover the residual energy (biogas) in the manure
2. to reduce odour emissions during storage and/or land spreading
3. to decrease the nitrogen content of the manure, with the aim of preventing possible ground and surface water pollution as a result of land spreading and to reduce odour
4. to allow easy and safe transportation of the manure to distant regions or when it has to be applied in other processes.

A number of manure treatment systems is applied, although the majority of farms in the EU are able to manage manure without recourse to the techniques listed below. Besides treatment on-farm, pig and poultry manure may also be (further) treated off-site in industrial installations such as, poultry litter combustion, composting or drying. The assessment of off-site treatment is outside the scope of this BREF.

Applied techniques for the on-farm treatment of pig and or poultry manure are:

- mechanical separation
- aeration of liquid manure
- biological treatment of pig slurry
- composting of solid manure
- composting of poultry manure with pine bark
- anaerobic treatment of manure
- anaerobic lagoons
- evaporation and drying of pig slurry
- incineration of broiler manure
- applying additives to manure

In general, on-farm processing of manure is BAT only under certain conditions (i.e. is a conditional BAT). The conditions of on-farm manure processing that determine if a technique is BAT relate to conditions such as the availability of land, local nutrient excess or demand, technical assistance, marketing possibilities for green energy, and local regulations.

The following Table 2 gives some examples on the conditions for BAT for pig manure processing. The list is not exhaustive and other techniques may also be BAT under certain conditions. It is also possible that the chosen techniques are also BAT under other conditions.

Under the following conditions	an example of what is BAT:
• the farm is situated in an area with nutrient surplus but with sufficient land in the vicinity of the farm to spread the liquid fraction (with decreased nutrient content), and • the solid fraction can be spread on remote areas with a nutrient demand or can be applied in other processes	mechanical separation of pig slurry using a closed system (e.g. centrifuge or press-auger) to minimise the ammonia emissions (Section 4.9.1)
• the farm is situated in an area with nutrient surplus but with sufficient land in the vicinity of farm to spread treated liquid fraction, and • the solid fraction can be spread on remote areas with a nutrient demand, and • the farmer gets technical assistance for running the aerobic treatment installation properly	mechanical separation of pig slurry using a closed system (e.g. centrifuge or press-auger) to minimise the ammonia emissions, followed by aerobic treatment of the liquid fraction (Section 4.9.3.) and where the aerobic treatment is well-controlled so that ammonia and N_2O production are minimised
• there is a market for green energy, and • local regulations allow co-fermentation of (other) organic waste products and land spreading of digested products	anaerobic treatment of manure in a biogas installation (Section 4.9.6.)

Table 2: Examples of conditional BAT on on-farm pig manure processing

An example of a conditional BAT on poultry manure processing is:

- applying an external drying tunnel with perforated manure belts, when the housing system for layers does not incorporate a manure drying system or another technique for reducing ammonia emissions.

Landspreading of manure from pigs and poultry

General

The Nitrate Directive lays down minimum provisions on the application of manure to land with the aim of providing all waters a general level of protection against pollution from nitrogen compounds, and additional provisions for applying manure to land in designated vulnerable zones. Not all provisions in this Directive are addressed in this document because of a lack of data, but when they are addressed, the TWG agreed that BAT on landspreading is equally valid inside and outside these designated vulnerable zones.

There are different stages in the process, from pre-production of the manure, to post-production and finally spreading on land, where emissions can be reduced and/or controlled. The different techniques that are BAT and that can be applied at the different stages in the process are listed below. However, the principle of BAT is based on doing all the following four actions:

- applying nutritional measures
- balancing the manure that is going to be spread with the available land and crop requirements and – if applied – with other fertilisers
- managing the landspreading of manure, and
- only using the techniques that are BAT for the spreading of manure on land and – if applicable – finishing off.

BAT is to minimise emissions from manure to soil and groundwater by balancing the amount of manure with the foreseeable requirements of the crop (nitrogen and phosphorus, and the mineral supply to the crop from the soil and from fertilisation). Different tools are available to balance the total nutrient uptake by soil and vegetation against the total nutrient output of the manure, such as a soil nutrient balance or by rating the number of animals to the available land.

BAT is to take into account the characteristics of the land concerned when applying manure; in particular soil conditions, soil type and slope, climatic conditions, rainfall and irrigation, land use and agricultural practices, including crop rotation systems. BAT is to reduce pollution of water by doing in particular all of the following:

- not applying manure to land when the field is:
  - water-saturated
  - flooded
  - frozen
  - snow covered
- not applying manure to steeply sloping fields
- not applying manure adjacent to any watercourse (leaving an untreated strip of land), and
- spreading the manure as close as possible before maximum crop growth and nutrient uptake occur.

BAT is managing the landspreading of manure to reduce odour nuisance where neighbours are likely to be affected, by doing in particular all of the following:
- spreading during the day when people are less likely to be at home and avoiding weekends and public holidays, and
- paying attention to wind direction in relation to neighbouring houses.

Manure can be treated to minimise odour emissions which can then allow more flexibility for identifying suitable sites and weather conditions for land application.

Pig manure

The emissions of ammonia to air caused by the landspreading can be reduced through the selection of the right equipment. The reference technique is a conventional broadcast spreader, not followed by fast incorporation. Generally, landspreading techniques that reduce ammonia emissions also reduce odour emissions.

Each technique has its limitations and is not applicable in all circumstances and/or on all types of land. Techniques that inject slurry show the highest reduction, but techniques that spread slurry on top of the soil followed by incorporation shortly afterwards can achieve the same reduction. However, this requires extra labour and energy (costs) and only applies to arable land that can easily be cultivated. BAT conclusions are shown in Table 3. The achieved levels are very site-specific and serve only as an illustration of potential reductions.

The majority of the TWG agreed that either injection or bandspreading and incorporation (if the land can be easily cultivated) within 4 hours is BAT for applying slurry to arable land, however there was a split view on this conclusion (see below).

The TWG also agreed that, for applying slurry to land, the conventional broadcast spreader is not BAT. However, four Member States proposed that where broadcasting is operated with a low spread trajectory, and at low pressure (to create large droplets; thereby avoiding atomisation and wind drift), and slurry is incorporated into the soil as soon as possible (at least within 6 hours), or is applied to a growing arable crop, these combinations are BAT. The TWG has not reached consensus on this latter proposal.

No reduction techniques for the spreading of solid pig manure have been proposed. However, for reducing ammonia emissions from the landspreading of solid manure, incorporation is the important factor not the technique on how to spread. For grassland, incorporation is not possible.

Split views:

1. Two Member States do not support the conclusion that bandspreading of pig slurry on arable land followed by incorporation is BAT. In their view applying bandspreading on its own, which has an associated emission reduction of 30 – 40 % is BAT for spreading pig slurry on arable land. Their argument is that bandspreading already achieves a reasonable emission reduction and that the extra handling required for incorporation is difficult to organise and the extra reduction that can be achieved does not outweigh the extra costs.

2. Another split view on incorporation involves solid pig manure. Two Member States do not support the conclusion that incorporation of solid pig manure as soon as possible (at least within 12 hours), is BAT. In their view incorporation within 24 hours, which has an associated emission reduction of around 50 %, is BAT. Their argument is that the extra ammonia emission reduction that can be achieved does not outweigh the extra costs and difficulties involved in organising the logistics for incorporation within a shorter time.

Land use	BAT	Emission reduction	Type of manure	Applicability
grassland and land with crop height below 30 cm	trailing hose (bandspreading)	30 % this may be less if applied on grass height >10 cm	slurry	slope (<15 % for tankers; <25 % for umbilical systems); not for slurry that is viscous or has a high straw content, size and shape of the field are important
mainly grassland	trailing shoe (bandspreading)	40 %	slurry	slope (<20 % for tankers; <30 % for umbilical systems); not viscous slurry, size and shape of the field, grass less than 8 cm high
grassland	shallow injection (open slot)	60 %	slurry	slope <12 %, greater limitations for soil type and conditions, not viscous slurry
mainly grassland, arable land	deep injection (closed slot)	80 %	slurry	slope <12 %, greater limitations for soil type and conditions, not viscous slurry
arable land	bandspreading and incorporation within 4 hours	80 %	slurry	incorporation is only applicable for land that can be easily cultivated, in other situations BAT is bandspreading without incorporation
arable land	incorporation as soon as possible, but at least within 12 hours	within: 4 hrs: 80 % 12 hrs: 60 – 70 %	solid pig manure	only for land that can be easily cultivated

Table 3: BAT on landspreading equipment for pig manure

Poultry manure

Poultry manure has a high available nitrogen content and it is therefore important to get an even spread distribution and an accurate application rate. In this respect the rota-spreader type is poor. The rear-discharge spreader and dual-purpose spreader are much better. For wet poultry manure (<20 % dm) from caged systems, such as described in Section 4.5.1.4, broadcasting with a low trajectory at low pressure is the only applicable spreading technique. However, no conclusion about which spreading technique is BAT has been drawn. For reducing ammonia emissions from landspreading poultry manure, incorporation is the important factor not the technique on how to spread. For grassland, incorporation is not possible.

BAT on landspreading – wet or dry – solid poultry manure is incorporation within 12 hours. Incorporation can only be applied to arable land that can be easily cultivated. The achievable emission reduction is 90 %, but this is very site-specific and serves only as an illustration of a potential reduction.

Split view:

Two Member States do not support the conclusion that incorporation of solid poultry manure within 12 hours is BAT. In their view incorporation within 24 hours, which has an associated ammonia emission reduction of around 60 – 70 %, is BAT. Their argument is that the extra ammonia emission reduction that can be achieved does not outweigh the extra costs and difficulties involved in organising the logistics for incorporation within a shorter time.

Concluding remarks

A feature of this work is that the ammonia emission reduction potential, associated with the techniques described in Chapter 4, are given as relative reductions (in %) against a reference technique. This is done because consumption and emission levels of the livestock depend on many different factors, such as the animal breed, the variation in feed formulation, production phase and management system applied, but also on other factors such as climate and soil characteristics. The consequence of this is that the absolute ammonia emissions from applied techniques, such as the housing systems, the storage of manure, and manure application to land, will cover a very wide range and make interpretation of absolute levels difficult. Therefore, the use of ammonia-reduction levels expressed in percentages has been preferred.

Level of consensus

This BREF has the support of most of the TWG members, although on five BAT conclusions split views have to be noted. The first two split views concern a housing system used for mating/gestating sows and growers/finishers. The third split view is on the landspreading of pig slurry by using a bandspreader followed by incorporation. The fourth and fifth split views concern the time taken between the landspreading and the incorporation of solid pig and poultry manure. All five split views are fully described in this executive summary.

Recommendations for future work

For future BREF reviews, all TWG members and interested parties should continue to collect data, in a format that can be easily compared, on the current emission and consumption levels and on the performances of techniques to be considered in the determination of BAT. On monitoring, very little information was made available and this should be considered a key issue in the future review of the BREF. Some other specific areas where data and information are missing concern the following:

- enriched cage systems for layers
- turkeys, ducks and Guinea fowls
- the use of litter in pig housing
- the associated costs and feeding equipment for the multiphase feeding of pigs and poultry
- techniques for the on-farm processing of manure, this needs further qualification and quantification to allow a better assessment for BAT considerations
- the use of additives in manure
- noise, energy, waste water and waste
- issues such as the dry matter content of manure and irrigation
- quantification of distances to watercourses when spreading manure to land
- quantification of sloping fields when spreading manure to land
- sustainable drainage techniques.

Animal welfare has been considered in this document. However, it would be useful to develop assessment criteria regarding animal welfare aspects of housing systems.

Suggested topics for future R&D projects

Section 6.5 in the main body of the BREF shows a list of about thirty topics that could be considered as potential topics for future Research and Development projects.

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).

Furthermore, Annex IV of the Directive contains a list of "considerations to be taken into account generally or in specific cases when determining best available techniques ... bearing in mind the likely costs and benefits of a measure and the principles of precaution and prevention". These considerations include the information published by the Commission pursuant to Article 16(2).

Competent authorities responsible for issuing permits are required to take account of the general principles set out in Article 3 when determining the conditions of the permit. These conditions must include emission limit values, supplemented or replaced where appropriate by equivalent parameters or technical measures. According to Article 9(4) of the Directive, these emission limit values, equivalent parameters and technical measures must, without prejudice to compliance with environmental quality standards, be based on the best available techniques, without prescribing the use of any technique or specific technology, but taking into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. In all circumstances, the conditions of the permit must include provisions on the minimisation of long-distance or transboundary pollution and must ensure a high level of protection for the environment as a whole.

Member States have the obligation, according to Article 11 of the Directive, to ensure that competent authorities follow or are informed of developments in best available techniques.

3. Objective of this Document

Article 16(2) of the Directive requires the Commission to organise "an exchange of information between Member States and the industries concerned on best available techniques, associated monitoring and developments in them", and to publish the results of the exchange.

The purpose of the information exchange is given in recital 25 of the Directive, which states that "the development and exchange of information at Community level about best available techniques will help to redress the technological imbalances in the Community, will promote the worldwide dissemination of limit values and techniques used in the Community and will help the Member States in the efficient implementation of this Directive."

The Commission (Environment DG) established an information exchange forum (IEF) to assist the work under Article 16(2) and a number of technical working groups have been established under the umbrella of the IEF. Both IEF and the technical working groups include representation from Member States and industry as required in Article 16(2).

The aim of this series of documents is to reflect accurately the exchange of information which has taken place as required by Article 16(2) and to provide reference information for the permitting authority to take into account when determining permit conditions. By providing relevant information concerning best available techniques, these documents should act as valuable tools to drive environmental performance.

4. Information Sources

This document represents a summary of information collected from a number of sources, including in particular the expertise of the groups established to assist the Commission in its work, and verified by the Commission services. All contributions are gratefully acknowledged.

5. How to understand and use this document

The information provided in this document is intended to be used as an input to the determination of BAT in specific cases. When determining BAT and setting BAT-based permit conditions, account should always be taken of the overall goal to achieve a high level of protection for the environment as a whole.

The rest of this section describes the type of information that is provided in each section of the document.

Chapter 1 provides general information at a European level on the agricultural sectors concerned. This includes economic data, consumption and production levels of eggs, poultry and pork as well as information on some legislative requirements.
In Chapter 2 the production systems and techniques are described that are commonly applied in Europe. This chapter provides the basis for the reference systems identified in Chapter 4 to assess the environmental performance of reduction techniques. It is not intended to describe only the reference techniques, nor can it cover all modifications of a technique that can be found in practice.

Chapter 3 provides data and information on current emission and consumption levels reflecting the situation in existing installations at the time of writing. It attempts to present the factors that account for the variation of consumption and emissions levels.

Chapter 4 describes the techniques that are considered to be most relevant for determining BAT and BAT-based permit conditions. This information includes consumption and emission levels considered achievable by using the technique, some idea of the costs and the cross-media effects associated with application, as well as the extent to which the technique is applicable to the range of installations requiring IPPC permits (e.g. new, existing, large or small installations). Techniques that are generally seen as obsolete are not included.

Chapter 5 presents the techniques and the emission and consumption levels that are considered to be compatible with BAT in a general sense. The purpose is thus to provide general indications regarding the emission and consumption levels that can be considered as an appropriate reference point to assist in the determination of BAT-based permit conditions or for the establishment of general binding rules under Article 9(8). It should be stressed, however, that this document does not propose emission limit values. The determination of appropriate permit conditions will involve taking account of local, site-specific factors such as the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. In the case of existing installations, the economic and technical viability of upgrading them also needs to be taken into account. Even the single objective of ensuring a high level of protection for the environment as a whole will often involve making trade-off judgements between different types of environmental impact, and these judgements will often be influenced by local considerations.

Although an attempt is made to address some of these issues, it is not possible for them to be considered fully in this document. The techniques and levels presented in Chapter 5 will therefore not necessarily be appropriate for all installations. On the other hand, the obligation to ensure a high level of environmental protection including the minimisation of long-distance or transboundary pollution implies that permit conditions cannot be set on the basis of purely local considerations. It is therefore of the utmost importance that the information contained in this document is fully taken into account by permitting authorities.

Since the best available techniques change over time, this document will be reviewed and updated as appropriate. All comments and suggestions should be made to the European IPPC Bureau at the Institute for Prospective Technological Studies at the following address:

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Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs

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SCOPE OF WORK

The scope of the BREF for intensive livestock is based on Section 6.6 of Annex I of the IPPC Directive 96/61/EC as 'Installations for the intensive rearing of poultry or pigs with more than:

(d) 40000 places for poultry
(e) 2000 places for production pigs (over 30 kg), or
(f) 750 places for sows.'

The Directive does not define the term **poultry**. From the discussion in the TWG it has been concluded that in this document the scope of poultry is:

- chicken laying hens and broilers
- turkeys
- ducks
- Guinea fowls.

However, only limited information was submitted on ducks and Guinea fowls and therefore these are only briefly discussed.

Hatching is not included in the poultry scope, as this is considered to be a separate activity and not an integrated activity of a layer or broiler farm.

The Directive distinguishes between farms with **pigs** and farms with **sows**. In practice, there are closed cycle farms which have both sows and grower/finishers. Typically their capacities are below the Annex I thresholds for both sectors, but they have at least an equal potential environmental impact as those farms that are identified in Annex I. The TWG concluded that breeding farms, growing/finishing farms and closed cycle farms are all included in the scope of this BREF in respect to the identification of reduction techniques and the assessment of BAT.

The rearing of pigs includes the rearing of weaners, whose growing/finishing starts at a weight level between 25 and 35 kg of live weight. The rearing of sows includes mating, gestating and farrowing sows (including offspring) and gilts (replacement sows).

In line with article 2.3 of Directive 96/61/EC, **a farm** is considered to be an installation that may consist of one or more stationary technical units and of all directly associated activities. For the scope of this work, the TWG included some techniques that they considered relevant but that are not always applied on installations covered by IPPC. For example, landspreading of manure is considered in great detail, although it is acknowledged that landspreading is often carried out by contractors and often not on land belonging to the farm where the manure has been generated. The reason for considering landspreading in such detail is to prevent the benefits of a measure applied by a farmer to reduce emissions in the beginning of a chain being cancelled out by later applying poor landspreading management or techniques at the end of the chain. Or in other words, because the main environmental impacts of farming all result from the manure from the animals, measures to decrease these emissions are not only limited to housing techniques and the storage of manure, but comprise measures throughout a whole chain of events, inclusive of feeding strategies and final landspreading, all of which are within the scope of this document.

Items not within the scope of this work are centralised manure or waste treatment facilities and alternative rearing systems, such as the free range farming of pigs by using rotating systems.

The following relevant **farm activities** are described, although it is acknowledged that not all of the activities will be found on every farm:

- farm management (including maintenance and cleaning of equipment)
- feeding strategy (and feed preparation)
- rearing of animals
- collection and storage of manure
- on-site treatment of manure
- landspreading of manure
- waste water treatment.

The environmental issues associated with the above listed activities include:

- the use of energy and water
- emissions to air (e.g. ammonia, dust)
- emissions to soil and groundwater (e.g. nitrogen, phosphorus, metals)
- emissions to surface water
- emissions of waste other than manure and carcases.

Factors such as animal welfare requirements, microbiological emissions and the antibiotic resistance of the animals, are important for the assessment of environmental techniques. They have been included in the assessment where information was made available. Issues concerning aspects such as, human health and animal products have not been part of the information exchange and are not covered in this BREF.

1 GENERAL INFORMATION

This chapter provides general information on pig and poultry production in Europe. It briefly describes the position of Europe on the world market and developments in the internal European market and those of its Member States. It introduces the main environmental issues associated with intensive pig and poultry farming.

1.1 Intensive livestock farming

Farming has been and still is dominated by family run businesses. Until the sixties and into the early seventies, poultry and pig production were only part of the activities of a mixed farm, where crops were grown and different animal species were kept. Feed was grown on the farm or purchased locally and residues of the animal were returned to the land as fertiliser. Very few examples of this type of farm still exist in the EU.

Since then, increasing market demands, the development of genetic material and farming equipment and the availability of relatively cheap feed encouraged farmers to specialise. As a consequence animal numbers and farm sizes increased and intensive livestock farming started. Feeds were often imported from outside the EU, since the amounts and types needed could not be produced locally. Intensive farming thus led to significant imports of nutrients that were not returned to the same land (via manure) that had produced the crops that provided the feed components. Instead the manure is applied on the available land. However, in many intensive livestock regions there is insufficient land available. In addition, higher nutrient levels were fed to the animals (sometimes more than was strictly necessary) to ensure optimum growth levels. These nutrients were consequently partly excreted in natural processes, thus increasing the level of nutrients in the manure even more.

Intensive livestock farming coincides with high animal densities. Animal density is itself considered a rough indicator of the amount of animal manure produced by livestock. A high density usually indicates that the mineral supply exceeds the requirements of the agricultural area to grow crops or to maintain grassland. Hence, data on the concentration of livestock production at a regional level are considered to be a good indicator of areas with potential environmental problems (e.g. nitrogen pollution).

In a report on the management of nitrogen pollution [77, LEI, 1999], the term livestock units (LU = 500 kg animal mass) is used to present the total size of the livestock population, allowing a summation of animal species according to their feed requirements. The meaning of the term “intensive livestock farming” in Europe is illustrated by using animal density expressed in the number of livestock units per hectare of utilised agricultural area (LU/ha).

Figure 1.1 shows animal density (in LU/ha) at regional levels. Animal density exceeds 2 LU/ha in most of the Netherlands, parts of Germany (Niedersachsen, Nordrhein-Westfalia), Brittany (France), Lombardy (Italy) and some parts of Spain (Galicia, Cataluña). A stocking density of 2 LU/ha is considered to be close to the amounts of nitrogen from livestock manure that may be applied in accordance with the Nitrates Directive. The picture also illustrates that for nearly all Member States the environmental impact of intensive livestock farming is a regional issue, but for a few countries like the Netherlands and Belgium it can almost be considered a national issue.

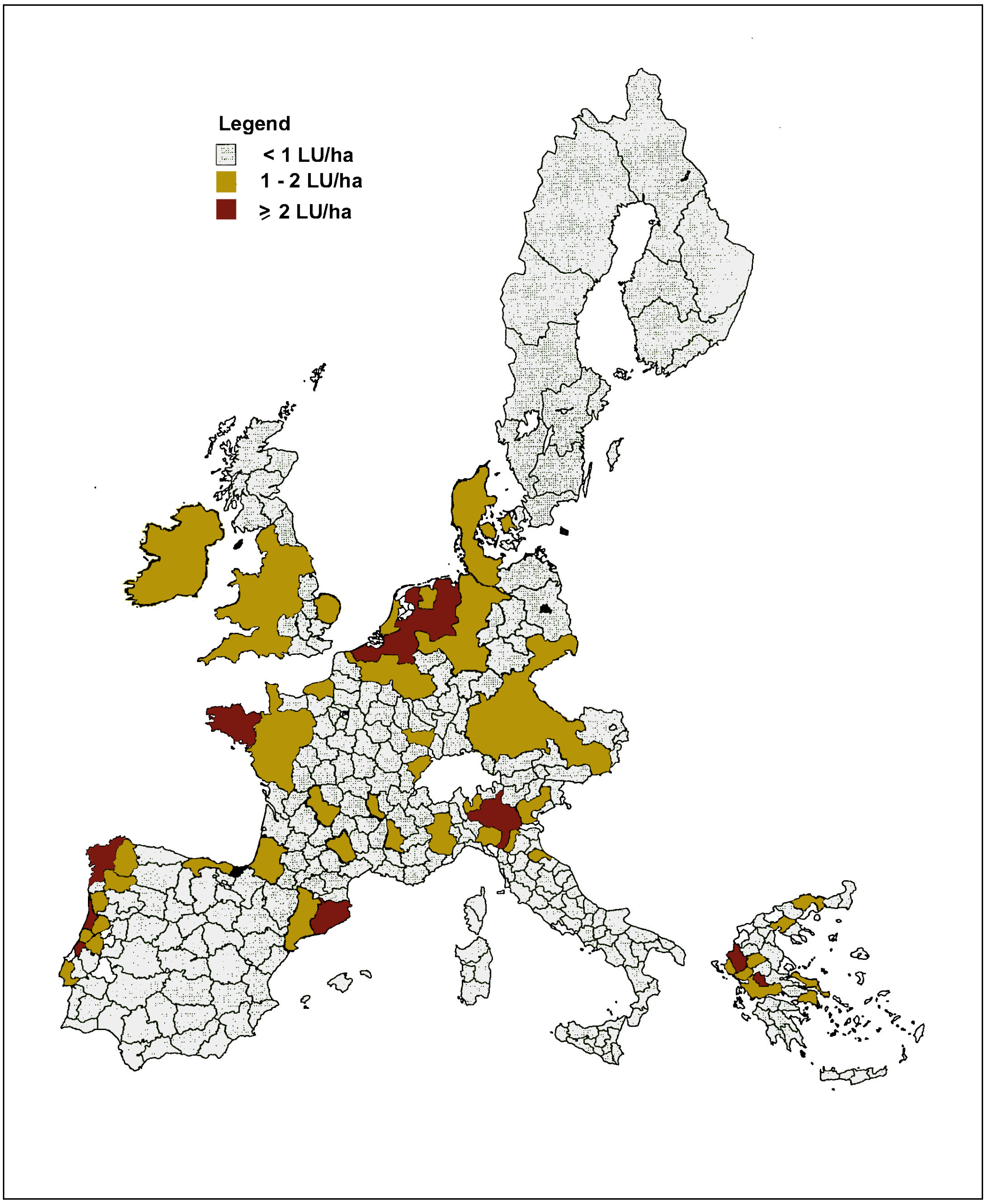

Figure 1.1: Animal density in the European Union, expressed as number of livestock units per hectare of utilised agricultural area
[153, Eurostat, 2001] [77, LEI, 1999]]

The areas with high livestock densities typically have many intensive pig and poultry farms each with a large number of animals. For example, the share of pigs and poultry exceeds 50 % in most of these regions and poultry accounts for more than 20 % of the regional livestock population in parts of France (Pays de la Loire, Bretagne), Spain (Cataluña) and the United Kingdom (East England). In some Member States there is a decline in the actual number of farms, but the remaining farms now tend to keep more animals and have higher production. In only a few Member States (e.g. Spain) are new enterprises being started or large facilities being installed. [77, LEI, 1999]

1.2 The poultry production sector in Europe

By far the majority of poultry farms are part of the production chain for chicken eggs or for chicken broilers. A comparatively small number of farms produces turkeys (meat) and ducks (for meat, foie gras or eggs); very little is known about the production of Guinea fowl. The following sections describe briefly the poultry sectors in Europe with the emphasis on chicken production, as only limited information has been submitted on the other production sectors. More detailed statistical data can be found in the annual reports of the European Commission (DG Agriculture and Eurostat [153, Eurostat, 2001]).

Poultry production data vary per poultry species and poultry breed and also somewhat per MS depending on market demands. Breeds are either selected for their egg producing capacities or growing (meat) potential. Table 1.1 shows some typical production data for poultry species under the scope of IPPC.

Types of technical elements	Laying hens	Broilers	Turkey		Duck
			M	F	
Production cycle (days)	385 – 450	39 – 45	133	98 – 133	42 – 49
Weight (kg)	1.85	1.85 – 2.15	14.5 – 15	7.5 – 15	2.3
Feed conversion ratios	1.77	1.85	2.72	2.37	2.5
Weight (kg)/m^2	no data	30 – 37	no data	no data	20

Table 1.1: Some typical poultry breeding data
[92, Portugal, 1999] [179, Netherlands, 2001] [192, Germany, 2001]

1.2.1 Egg production

Worldwide, Europe is the second largest producer of hen eggs with about 19 % of the world total, equalling 148688 million eggs per year (1998), and it is expected that this production will not change significantly in the coming years. In 1999, the EU-15 had about 305 million layers producing 5342 million tonnes of eggs, or, at an average of about 62 grams per egg, approximately 86161 million eggs. This means that on average about 282 saleable eggs per hen per year were produced (the actual number will be slightly higher, as some eggs will be lost due to cracks and dirt).

Egg production follows a cyclical pattern as production is increased/reduced after periods of favourable/low prices [203, EC, 2001].

Eggs for human consumption are produced in all Member States. The largest producer of eggs in the EU is France (18 % of the flock and 17 % of the egg production) followed by Germany (14 % of the flock and 16 % of egg production), Italy (15 % of the flock and 14 % of the egg production) and Spain (14 % of the flock and 14 % of the egg production) which all have comparable production levels, closely followed by the Netherlands (12 % of the flock and 13 % of the egg production). Of the exporting Member States, the Netherlands is the largest exporter with 65 % of its production followed by France, Italy and Spain, while in Germany consumption is higher than production.

Concerning the housings of the animals, it is expected that reductions in stocking density under Directive 99/74/EC will result in units with a smaller number of animal places, as only a reduced number of hens could be legally housed in cages. As a consequence, the number of installations with more than 40000 places is forecast to decrease; as up to 20 % [203, EC, 2001] of the birds may have to be removed to comply with the new regulations. The current numbers of farms under IPPC (over 40000 bird places) are listed in Table 1.3.

The majority of laying hens in the EU are kept in cages, although particularly in Northern Europe, non-cage egg production has gained in popularity over the past ten years. For example, the United Kingdom, France, Austria, Sweden, Denmark and the Netherlands have increased the proportion of eggs produced in systems such as barn, semi-intensive, free range and deep litter.

Deep litter is the most popular non-cage system in all Member States, except for France, Ireland and the United Kingdom, where semi-intensive systems and free range are preferred.

The number of layers kept on one farm varies considerably between a few thousand and up to several hundred thousand. A relatively small number of farms per Member State are expected to be under the scope of the IPPC Directive. Of other egg laying poultry species only a couple may be found with 40000 places or more.

Most of the EU-produced consumption eggs (about 95 %) are consumed within the European community itself. Average annual consumption per capita in 2000 was about 12.3 kg. Compared with 1991, consumption levels show a slight decline (Figure 1.2).

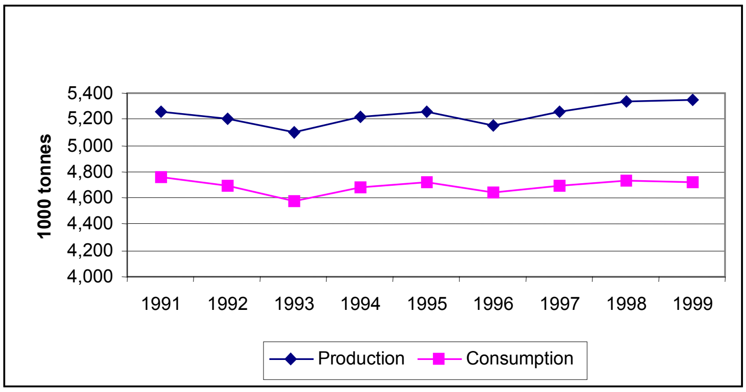

Figure 1.2: Dynamics of egg production and consumption in the EU
[153, Eurostat, 2001]

The production chain of the egg production sector is a sequence of different activities, each representing one breeding or production step. The breeding, hatching, rearing and egg laying often take place at different sites and on different farms to prevent the possible spread of diseases. Layer farms, particularly the larger ones, often include grading and packing of eggs after which the eggs are delivered directly to the retail (or wholesale) market.

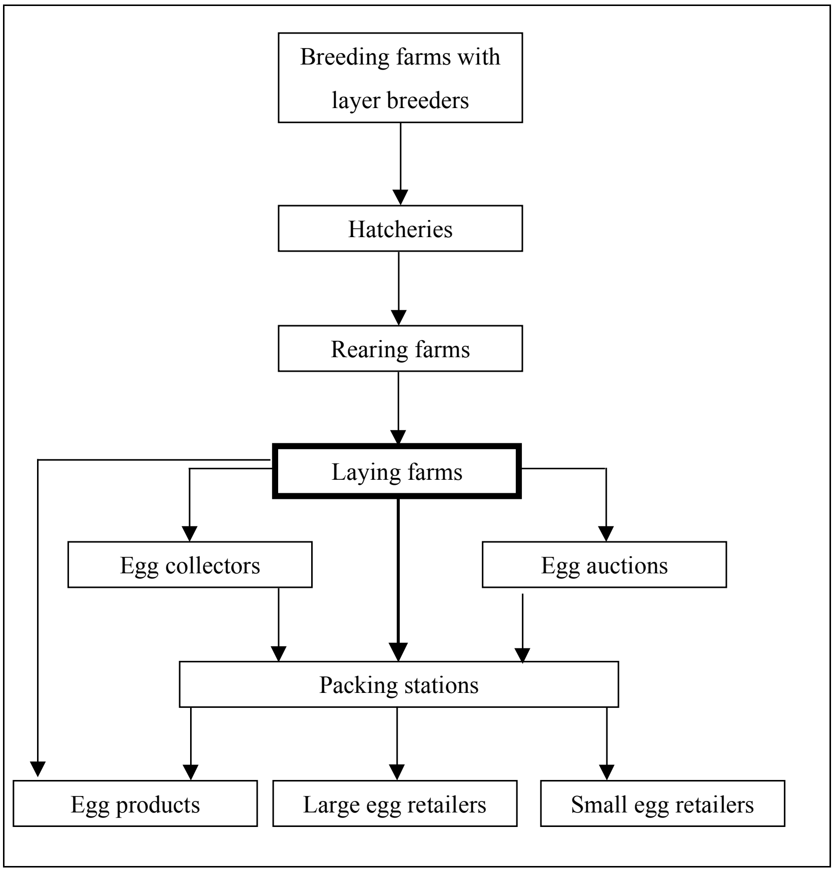

Figure 1.3: Example of the production chain of the egg production sector
[26, LNV, 1994]

No information was provided on the structure, position and developments of other egg producing sectors (in particular ducks). They form only a very small activity in comparison with the chicken egg production sector.

1.2.2 Broiler production

According to DG Agriculture unit D2, the total production of poultry meat in the EU-15 was 8.784 megatonnes for the year 2000, of which 8.332 megatonnes were consumed within the EU. The balance, 0.452 megatonnes (5.1 %) was net export. [203, EC, 2001]

The biggest producer of poultry meat in the EU-15 (year 2000) is France (26 % of EU production), followed by United Kingdom (17 %), Italy (12 %) and Spain (11 %). Some countries are clearly export-oriented, such as the Netherlands, where 63 % of the production is not consumed within the own country, as well as Denmark, France and Belgium where 51 %, 51 % and 31 % respectively of production are not consumed within the own country. On the other hand, some countries such as Germany, Greece and Austria have consumptions higher than their own production; in those countries, 41 %, 21 % and 23 % respectively of total consumption is imported from other countries. [203, EC, 2001]

Production of poultry meat has been increasing since 1991 by an average of 232000 tonnes per year. The largest EU producers (France, UK, Italy and Spain) all showed an increase in their poultry meat production.

From 1991 and up to the year 2000, France and the United Kingdom increased their production by 24.4 % and 38.3 % respectively, while Spain increased its by 11.9 % [203, EC, 2001]. While egg production in the European Union can be described as “flat”, the sector’s growth is in poultry meat. Public concern about the consumption of beef and veal and pork may further enhance this growth.

Personal consumption has been increasing by an average of 459 grams per person; that means that EU-15 consumption increased by 170666 tonnes per year (1999). Exports to other countries have also been increasing, by an average of 38000 tonnes per year.

The Member States with the largest consumption in the EU are France, UK, Germany and Spain. They all increased their consumption between 1991 and 2000: France by 21 %, Germany and Spain by 41 % and 11 % respectively. The United Kingdom became the main consumer of poultry meat from 1994 onwards; its consumption has increased by 51 %. [203, EC, 2001]

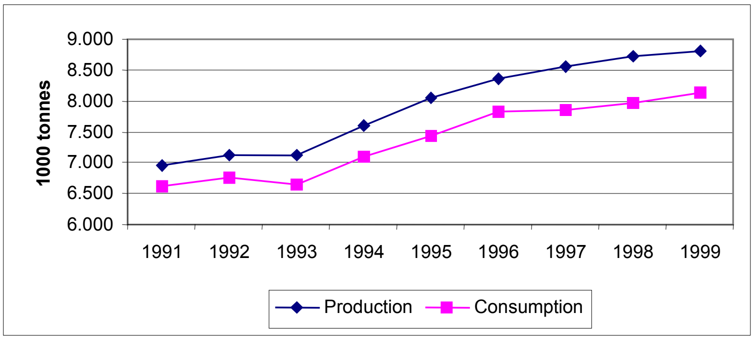

Figure 1.4: Dynamics of poultry meat production and consumption in the EU
[153, Eurostat, 2001]

The production of broilers is a specialised part of the broiler production chain. The different steps in the broiler chain are shown in Figure 1.5. This document addresses in particular the broiler production farms. Broilers are generally not housed in cages, although cage systems exist. The majority of poultry meat production is based on an all-in all-out system applying littered floors. Broiler farms with over 40000 bird places are quite common in Europe. The duration of a production cycle depends on the required slaughter weight, feeding and the condition (health) of the birds and varies between 5 weeks (Finland) and 8 weeks [125, Finland, 2001], after which the broilers are delivered to the slaughterhouse. After every cycle the housing is fully cleaned and disinfected. The length of this period varies from 1 week up to two (Finland, UK) or even three weeks (Ireland).

A type of production that has so far been specific to France involves the so-called "red label" broiler. The broilers have permanent access to the open range and are slaughtered at the minimum age of 80 days, at more than 2 kg live weight. This type of production is gaining popularity and represents to date (year 2000) close to 20 % of the French broiler consumption. [169, FEFAC, 2001] (with reference to ITAVI, 2000)

The turkey production sector is the largest of the other poultry meat producing sectors. It is an important sector in four Member States (France, Italy, Germany and the UK). Since 1991 the production in the EU has increased by 50 %. [203, EC, 2001] Annual patterns of turkey poult placings in the EU show similar patterns with four peak placings in February-March, June, August-September and November-December.

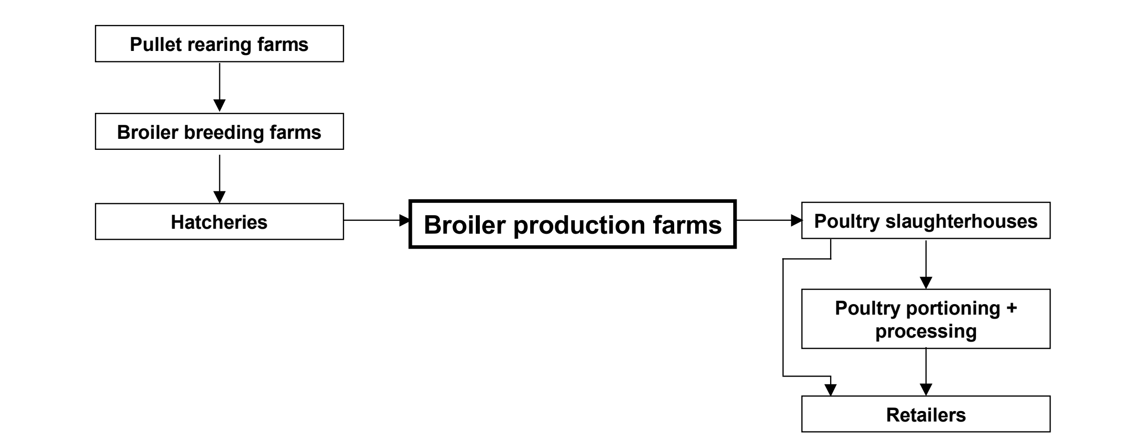

Figure 1.5: Example of the production chain of the broiler production sector
[26, LNV, 1994]

1.2.3 Economics of the poultry sector

The majority of poultry farms are family run enterprises. Some farms belong to large holdings carrying out all that activities that are part of a production line, from production to retail and including animal feed supply. The investment in livestock and production items (equipment, housing) is linked with the farms' net margin. The net margin of poultry farms varies in each Member State and depends on production costs and product price. Production costs may consist of:

- costs for chicks (except in integrated systems)
- feed costs
- veterinary costs
- labour costs
- energy costs
- maintenance of equipment and buildings
- depreciation costs for equipment and buildings
- interest.

The cost of egg production is also clearly related to production factors such as the stocking density. Production costs are lowest in multi-bird cages; costs increase with increasing space allowances in cages and with the use of non-cage systems. The production of free-range eggs is considerably more costly than any other system. Therefore higher welfare standards currently being adopted in the EU as a result of Directive 1999/74/CE, which requires more space for the birds, will increase production costs. It is expected that this may lead to increasing imports from countries with lower welfare standards (and therefore lower production costs) at the detriment of EU produced eggs if consumers are not prepared to pay a higher price.

System	Available area	Relative costs
Cage	450 cm^2/bird	100
Cage	600 cm^2/bird	105
Cage	800 cm^2/bird	110
Aviary/Perchery	500 cm^2/bird	110
Aviary/Perchery	833 cm^2/bird	115
Deep litter	1429 cm^2/bird	120
Free range	100000 cm^2 range/bird	140

Table 1.2: Summary of egg production costs in different systems
[13, EC, 1996]

The gross income of a farm depends on the number of eggs or kg of live weight that can be sold and the prices the farmer receives (including the price of end-of-lay hens). The prices of poultry products are not guaranteed or fixed and fluctuate with price fluctuations in the market. This market is in turn affected by the dynamics and the structure of the large grocery retailers (15 in 1999), who are the main outlets for the poultry products and are therefore responsible for the major part of the annual turnover of poultry products.

In 1999, the average price for eggs in the European Union was EUR 78.87/100 kg (EUR 0.049/egg). In 2000, the average price for eggs was EUR 100.39/100 kg (EUR 0.062/egg). Egg and layer feed prices have been decreasing since 1991. Overall, the gross margin for egg production has slightly decreased since 1991. [203, EC, 2001]

In 1998, the average price for broiler meat in the European Union was EUR 143.69 /100 kg. In 1999, the average price for poultry meat from January to September was EUR 133.44 /100 kg. Meat prices have been decreasing ever since 1991, but at the same time feed prices have decreased as well. Generally, since 1991 the gross margin for broiler production has decreased.

Prices are also affected when the sector is hit by product contamination (salmonella and dioxins) or by problems that affect other animal product markets (swine fever, BSE). These effects can be regional, but in particular with export oriented MSs, problems can be easily transferred to the wider European market.

For example, the dioxin crisis in mid-1999 associated with the contamination of animal feedstuffs severely affected the markets for poultry meat and eggs in Belgium.. As products were removed from the shelves of retail outlets, both consumption and prices fell. Whilst the crisis had a severe effect on the financial position of the Belgian industry, neighbouring MSs also felt the effects as both their consumption and prices showed a decline as well. On the other hand, outbreaks of foot-and mouth disease, swine fever and BSE in particular shifted consumer behaviour towards an increased consumption of poultry products.

Few economic data have been submitted on fresh turkey production. The September 2000 National Farmers Union (NFU) market report on fresh turkeys reports on the costs (per bird marketed). As an indication of costs, costs for the finishing of hens were EUR 18 per bird (6.4 kg deadweight) to 22 per bird (6.3 kg deadweight) and for stags EUR 19.5 per bird (6.7 kg deadweight) to 23.4 per bird (10 kg deadweight). These costs depend on the price for a poult, whose starting weight will vary, and on the end weight of the birds when they are sold. Costs also include plucking and bleeding. [126, NFU, 2001]

Member State	Layers			Broilers			Turkeys			Ducks			Guinea fowls		
	Birds (10^6)	Farms	IPPC	Birds (10^6)	Farms	IPPC	Birds (10^6)	Farms	IPPC	Birds (10^6)	Farms	IPPC	Birds (10^6)	Farms	IPPC
B (2000) [1)]	12.7	4786	172 (50000) [2)]	26.6	2703	320 (50000) [2)]	0.3	232	n.d.	0.04	853	n.d.	0.06	206	n.d.
D	n.d.	n.d.	549 (20000)[2)]	n.d.	n.d.	432 (25000) [2)]	n.d.	n.d.	264 (10000)[2)]	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
E	40.7	n.d.	n.d.	n.d.	n.d.	n.d.	0.135	n.d.	n.d.	0.092	n.d.	n.d.	n.d.	n.d.	n.d.
FIN (1999) [1)]	3.6	4000	2	5.5	227	64	0.150	55	n.d.	0.003	2	n.d.	none	n.d.	n.d.
IRL	n.d.	n.d.	n.d.	n.d.	n.d.	141	n.d.	n.d.	n.d.	n.d.	1	n.d.	n.d.	n.d.	n.d.
I	47.2	2066	n.d.	475.7	2696	n.d.	38.9	750	n.d.	10.1	n.d.	n.d.	25.3	n.d.	n.d.
NL	32.5	2000	n.d.	50.9	1000	n.d.	1.5	125	n.d.	1	65	n.d.	0.2	20	n.d.
A	n.d.	n.d.	22	n.d.	n.d.	11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
P (1998) [1)]	6.2	622	25 (50000) [2)]	199	3217	43 (50000) [2)]	4.7	176	20 (50000)[2)]	0.3	12	0	very few	n.d.	n.d.
S	2.2	900	0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
UK	n.d.	n.d.	>200	n.d.	n.d.	700	n.d.	n.d.	20	n.d.	n.d.	10	n.d.	n.d.	n.d.

1) year of report
2) the number of places, some data were reported with different thresholds than the IPPC-threshold as IPPC threshold in practical statistics does not apply.
"n.d." no data submitted or available

Table 1.3: Number of birds, total farms and farms under definition of Section 6.6 of Annex 1 of Council Directive 96/69/EC for different European Member States
Resources: as reported by Member States in comments and national BAT documents (see references)

1.3 The pig production sector in Europe

1.3.1 Dimension, evolution and geographical distribution of the pig production sector in Europe

The dynamics of the European pig producing industry are closely followed and described in detail by national and European institutes (e.g. FAO, LEI, MLC, Eurostat). The data in the following sections have been derived from these sources to draw a general picture of the pig producing sector.

In the EU-15, pig production increased by 15 % between 1997 and 2000. The total number of pigs in December 1999 was 124.3 million, which was a 5.4 % increase as compared with 1997. This increase was mainly attributable to growth in pig populations in Spain, the Netherlands and Germany (the latter reflecting a recovery following the outbreak of classical swine fever), which offset declines in the United Kingdom population.

In 1999 production slowed down, but the effects of the recent foot-and-mouth outbreak are not included. Yearly patterns show that pigmeat production is always highest in the last quarter of the year.

Although the pig population surveys conducted in the Member States in December 2000 reveal a slight decline compared with 1999 (-1.2 %), the overall level remained high (122.9 million animals). The biggest falls were recorded in Austria, Finland, Sweden and UK, whilst the total pig population rose by approximately 6.1 % in Denmark.

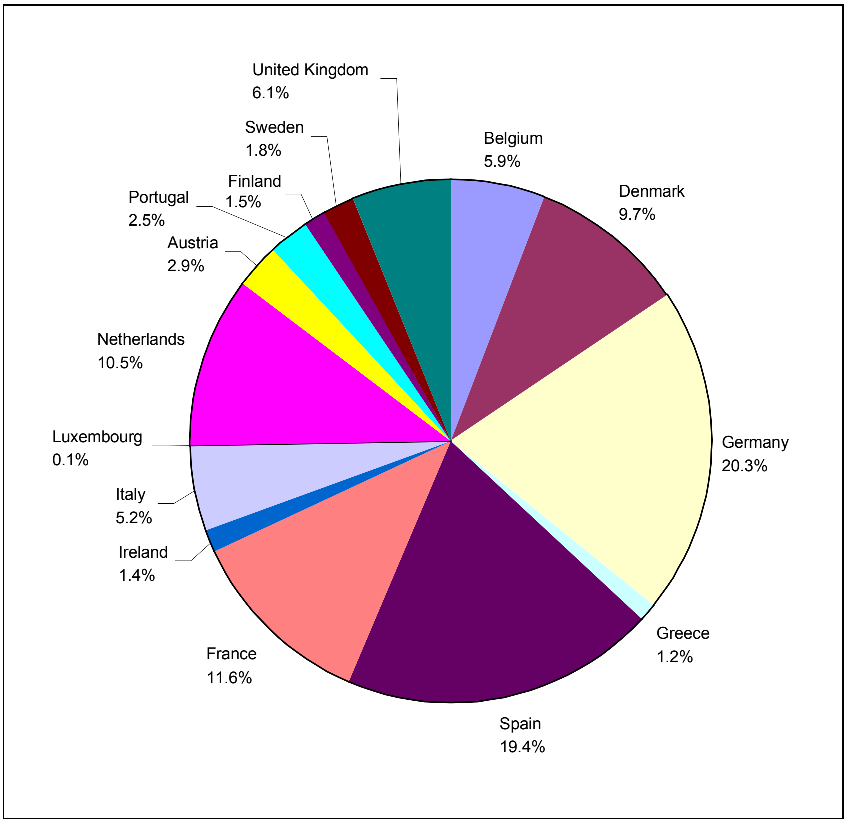

Figure 1.6: Distribution of breeding sows in Europe for each Member State in 1998 [Eurostat Nov/Dec 1998 Surveys]

In 2000, the pig population in EU-15 consisted of an estimated 33.4 million piglets (< 20 kg), 46.9 million finishers (> 50 kg) and 12.9 million breeders (> 50 kg), 0.4 million boars and 21.1 million sows (12.5 breeding and 8.6 mated).

The major pig breeding Member States are Germany, Spain, France, the Netherlands and Denmark with a combined share of 71 % of the breeding sows in 1998 (Figure 1.7). Data for 2000 show that this has increased slightly (73 %), with increases in Denmark and Spain offsetting clear declines in the Netherlands and, to a lesser extent, in Germany.

Sow numbers are reflected in terms of pig output or gross indigenous production (GIP). Again, Germany, Spain, France, Denmark and the Netherlands produced 69.5 % of EU-15 pigs in 1998 (Figure 1.7) and increased their production, so that in 2000 they account for more than 73 % of the total Community output. GIP trends in the Member States show that Ireland, the Netherlands and the UK, in particular, have reduced their production.

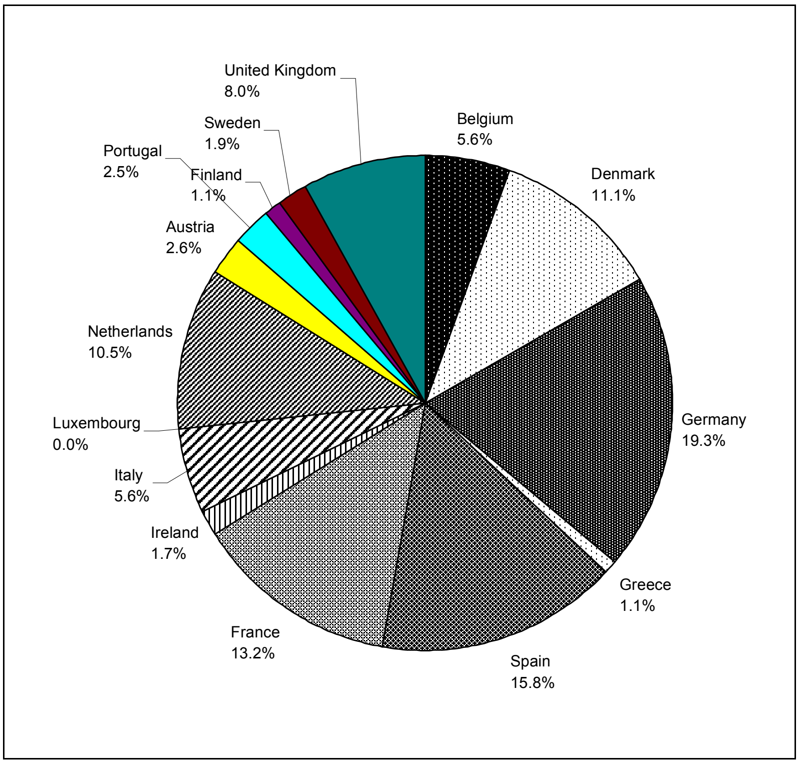

Figure 1.7: Gross indigenous pig production in 1998
[Eurostat Nov/Dec 1998 surveys]

Pig farms vary considerably in size. The most recent figures available on unit size relate to 1997. While pig numbers have increased in Europe, the number of units has declined, but individual farm facilities have become larger. The largest average unit size is found in Ireland (1009 heads), followed by the Netherlands (723), Belgium (629), Denmark (605) and the United Kingdom (557). Throughout the EU-15, 71 % of pig farmers have less then 10 pigs. This is common in Greece, Spain, France, Italy, Austria and Portugal, where over 50 % of holders have less than 10 pigs (Figure 1.8). A further 10 percent of units in the EU have herd sizes of between 10 and 49 pigs. Although most holders have small units, the majority of pig production (88 %) is associated with units larger than 200 pigs, 52 % of the units have even more than 1000 pigs (Figure 1.9).

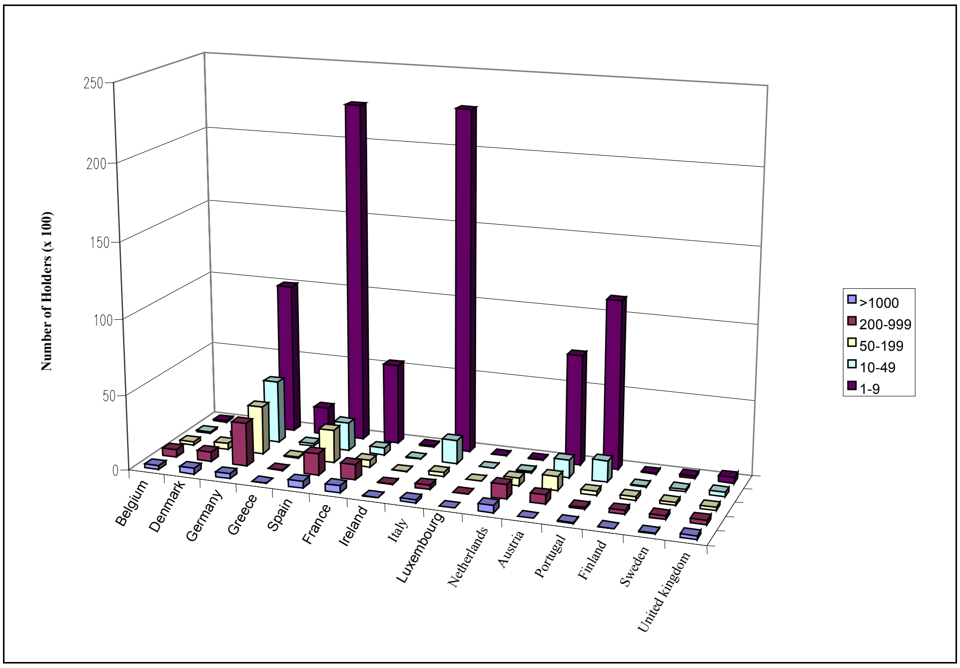

Figure 1.8: Number of holders by unit size in 1997. Legend indicates unit size (in reverse order) [153, Eurostat, 2001]

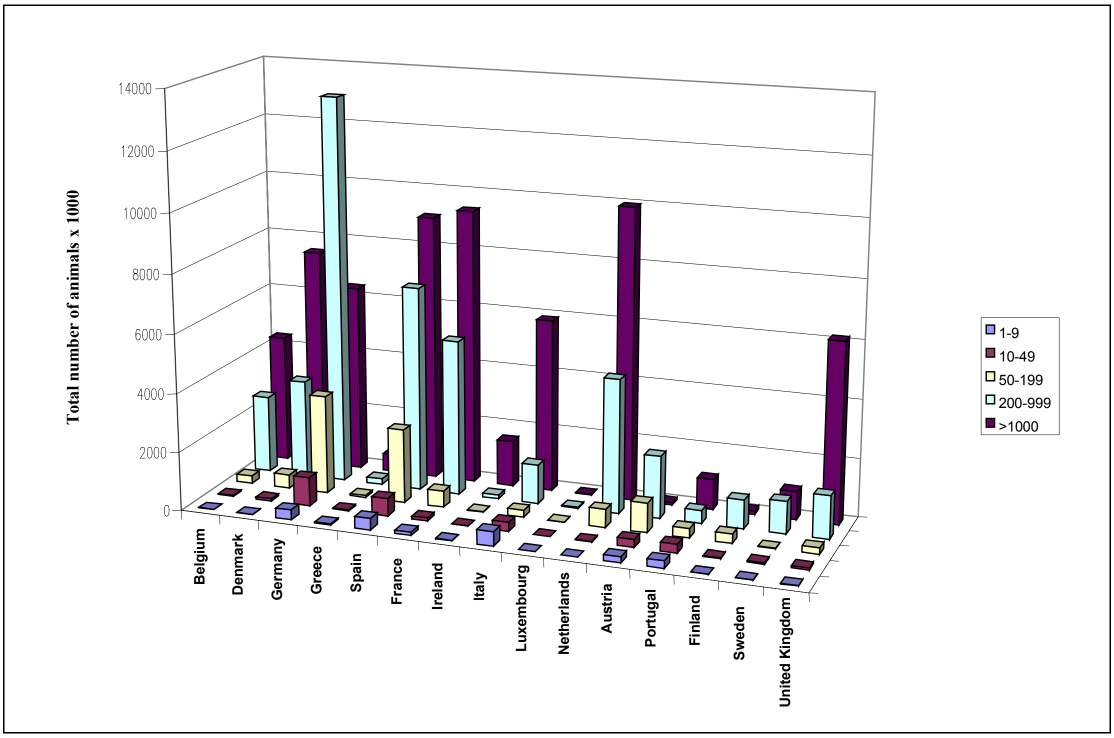

Figure 1.9: Number of animals in unit size categories (1997) [153, Eurostat, 2001]

Across the EU-15, 67 % of sows are in units of more than 100 sows (Figure 1.10). In Belgium, Denmark, France, Ireland, Italy, the Netherlands and the United Kingdom this figure is over 70 %. In Austria, Finland and Portugal smaller sow units are predominant.

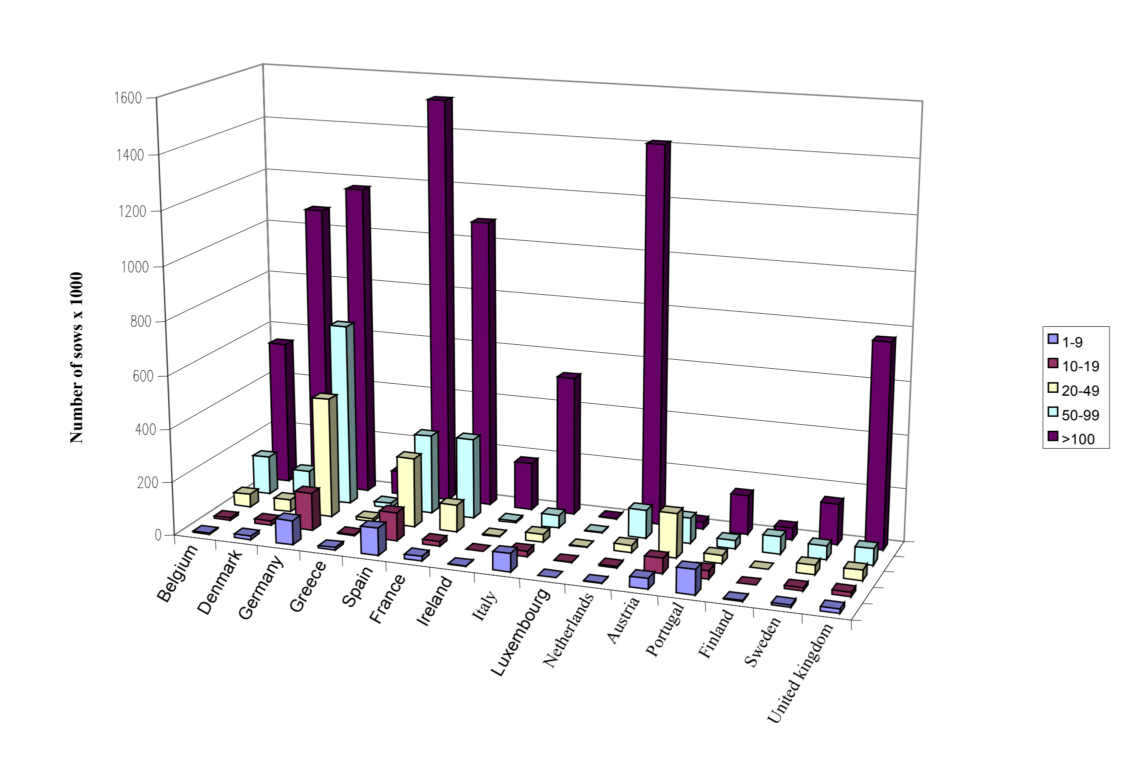

Figure 1.10: Number of sows in different sized units (1997). Legend indicates size of unit in terms of number of sows
[153, Eurostat, 2001]

The majority of pigs for fattening (81 %) are reared on units of 200 pigs or more (Figure 1.11) and 63 % of them on units of more than 400 pigs. 31 % of fattening pigs are reared on holdings of more than 1000 pigs. The industry in Italy, United Kingdom and Ireland is characterised by units of more than 1000 fattening pigs. Germany, Spain, France and the Netherlands have significant proportions of pigs in units of between 50 and 400 fattening pigs.

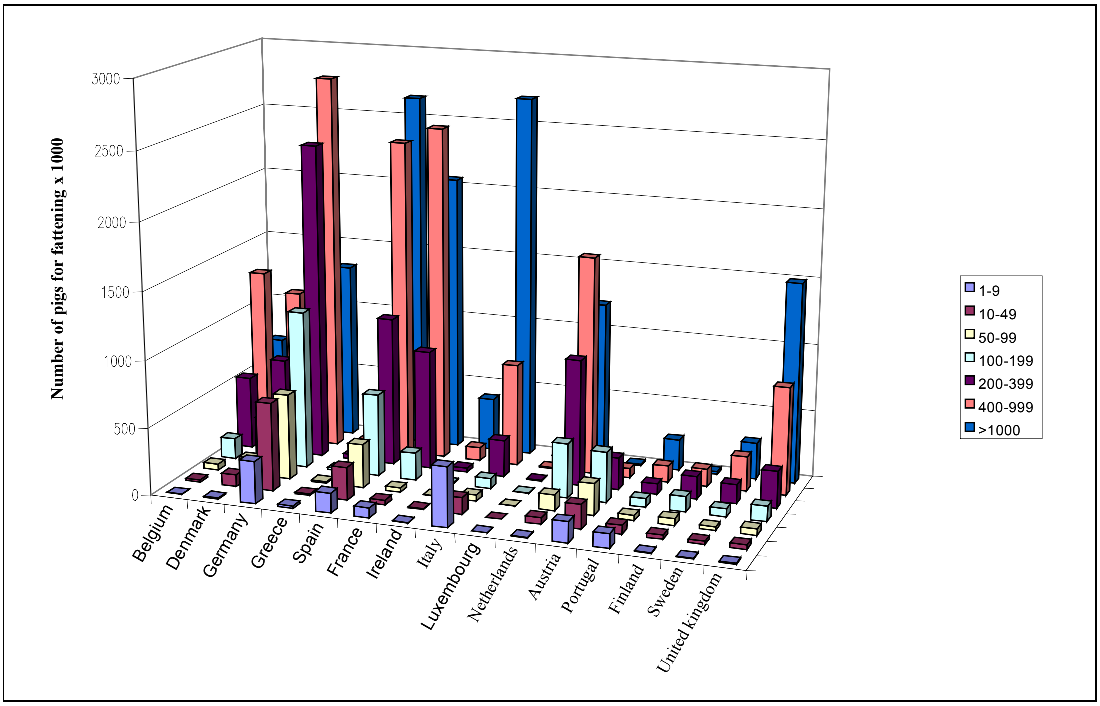

Figure 1.11: Number of pigs for fattening on various size units (1997)
[153, Eurostat, 2001]

From these numbers it is obvious that only a relatively small number of farms will fall within the definition of Section 6.6 of Annex 1 of Council Directive 96/69/EC (Table 1.4).

	Pigs (>30 kg)			**Sows**		
Member State	**Number of animals (million)**	**Number of farms**	**Farms under IPPC**	**Number of animals (million)**	**Number of farms**	**Farms under IPPC**
B (2000)	2.9	7487	71	0.8	7450	n.d.
DK (1997)	6.2	n.d.	n.d.	1.2	n.d.	n.d.
D (1997)	15.6	n.d.	261	2.6	n.d.	281
E (1997)	11.6	n.d.	822	2.1	n.d.	252
F (1997)	9.9	n.d.	n.d.	1.4	n.d.	n.d.
FIN (1997)	0.79	4727	6	0.18	n.d.	n.d.
IRL (1997)	1.0	n.d.	n.d.	0.19	n.d.	n.d.
I (2001)	0.958	n.d.	407	0.147	n.d.	116
NL (1997)	7.2	n.d.	n.d.	1.4	n.d.	n.d.
A	n.d.	n.d.	6	n.d.	n.d.	n.d.
P (1997)	1.3	n.d.	n.d.	0.33	n.d.	n.d.
UK (1997)	4.7	n.d.	n.d.	0.9	n.d.	n.d.

1997-data are reported in [10, Netherlands, 1999] with reference to Eurostat '97
Belgium data for pigs refer to pigs >50 kg live weight
German data on IPPC-farms refer to more than 1500 pigs and more than 500 sows
Spanish data on IPPC-farms refer to fewer than 750 sows and more than 2000 pigs
Finish data refer to growers >20 kg live weight
n.d. = no data

Table 1.4: Number of pig farms in European Member States under definition of Section 6.6 of Annex 1 of Council Directive 96/69/EC

In most countries, pig production is concentrated in certain regions, e.g. in the Netherlands pig production is concentrated in the southern provinces. Based on 1994 data, densities of 2314 pigs per 100 ha in Noord-Brabant and 1763 in Limburg have been quoted.

Pig farming in Belgium is strongly concentrated in West Flanders (approximately 60 % of the pig population). In France intensive pig production is concentrated in Brittany (approximately 50 % of the pig population), where larger herd sizes are common.

In Germany pig production is concentrated in the north-west, i.e. in the northern counties of Westphalia and the southern counties of the Weser-Ems-Region in Lower Saxony. Data for 1994 suggests a maximum concentration of 1090 pigs per 100 ha in the Vechta region.

Italy has concentrations of pig production in the Po valley. Currently 73.6 % of Italian pig farming assets are located in the four regions of Lombardia, Emilia-Romagna, Piemonte and Veneto within the Po valley.

The spatial density of pig production is used as an indicator of the potential environmental impact of pig production. Data on total pig numbers per 100 ha of utilised agricultural area (UAA) for each Member States are presented in Figure 1.12. Highest densities are apparent in the Netherlands, Belgium and Denmark, but national statistics can hide regional concentrations of pig production and, for most European MSs, high animal densities and intensive livestock farming are regional concerns (see Figure 1.1).

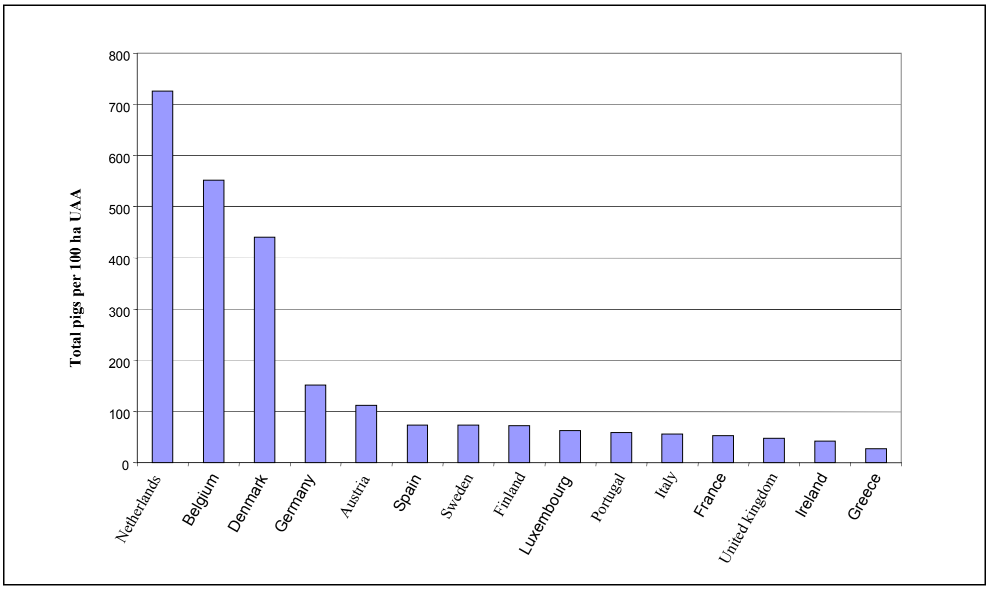

Figure 1.12: Spatial density of pig production in the EU-15
[153, Eurostat, 2001]

1.3.2 Production and consumption of pork

The EU-15 accounts for approximately 20 % of the world pork production, as indicated by slaughtered carcase weight. In 2000, the industry in the EU-15 was responsible for an average monthly pork slaughtering of 1.464 (1.328 – 1.552) million tonnes of carcase weight, whether of indigenous or foreign origin, which totalled 17.568 million tonnes of pork in a year. For comparison, this was more than twice the carcase weight of beef and veal slaughterings over the same period of time [153, Eurostat, 2001].

The average weight to which pigs are finished and their average carcase weight vary throughout the EU. This has a significant impact in relation to the period of time that the pigs are housed, the quantity of feed consumed, and the volume of effluent produced. For example in Italy, heavy pigs are reared to an average live weight of 156 kg, yielding a carcase weight of 112 kg. Generally, higher than average carcase weights (in excess of 80 kg) are also produced in Austria, Germany and Belgium (finished 117 kg / carcase 93 kg) (see Figure 1.13).

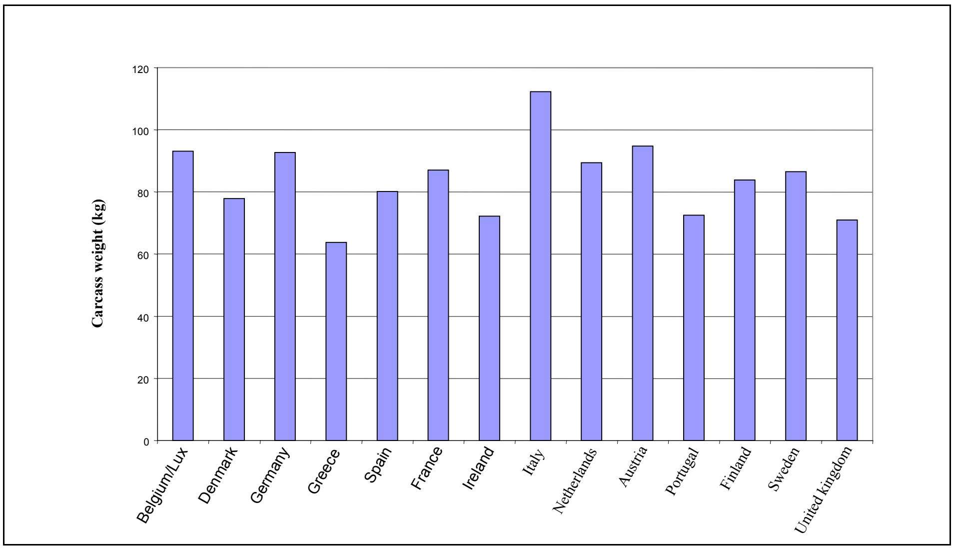

Figure 1.13: Carcase weight of slaughtered pigs for each Member State
[153, Eurostat, 2001]

Comparing data on carcase weight and live weight, allows in general an average ratio to be derived where the carcase weight is approximately 75 % of live weight. As an expected 204 million pigs were slaughtered in 2000 with an estimated average live weight of 100 kg, this means that the indigenous pig slaughterings have amounted to an estimated 15.3 million tonnes of carcase weight. The major producer of pork is Germany (20 %), followed by Spain (17 %), France (13 %), Denmark (11 %) and the Netherlands (11 %). Together they produce more than 70 % of the EU-15 indigenous production.

Not all of this production is consumed in the Member States themselves. As a whole, the EU is a net exporter of pork, importing only a very small amount (Figure 1.14). Not every major producer is an exporter, for instance Germany is a major producer but still imported about twice as much as it exported in 1999.

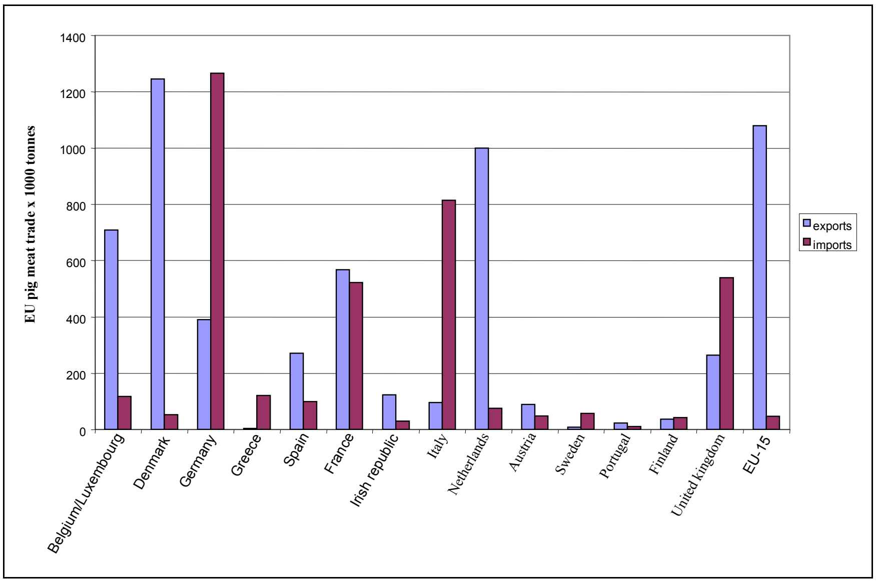

Figure 1.14: Pigmeat trade by European Member States
[Eurostat, 1999]

With varying live weights at the end of the finishing period, the period of time needed for rearing a pig also varies in the EU-15. Many factors influence this, such as the feeding, farm management and market demands requiring a certain quality pork. As an example, some production data are shown describing production in the UK.

Species	Characteristic	Unit	Level
Breeding	Offspring	pigs/sow/year	22
Weaners	Live weight range	kg	7 – 35
	Gain	g/day	469
	FCR	kg feed/kg live weight	1.75
Growers/finishers	Live weight range	kg	35 – onwards
	Gain	g/day	630
	FCR	kg feed/kg live weight	2.63

Table 1.5: General production levels pig farming UK
[131, FORUM, 2001]

On an EU-wide basis, the consumption of pig meat is higher than for any other meat. Over the past two years, competitive prices and plentiful supplies have driven consumption to new record levels. Per capita consumption in 2000 as a whole was forecast to be about 43.5 kg compared with 41.2 kg in 1997 [203, EC, 2001]. (See Figure 1.15).

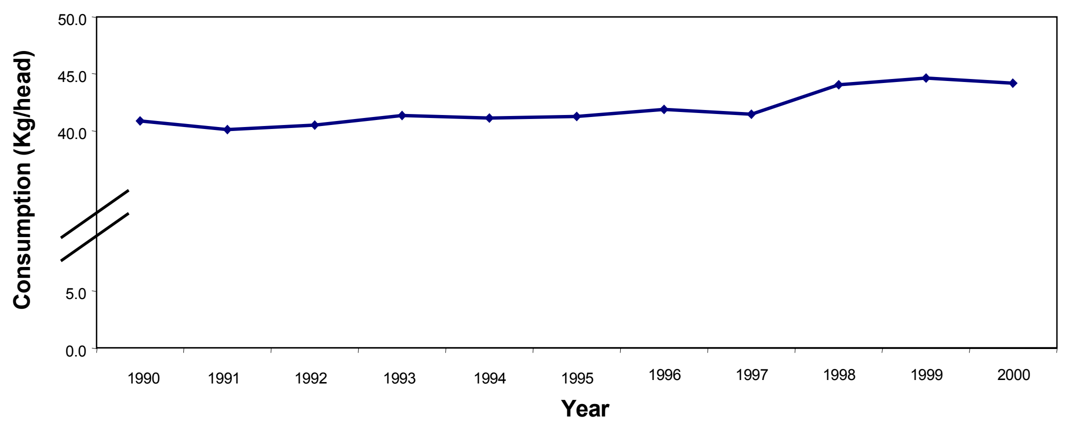

Figure 1.15: Consumption of pig meat per capita (kg/person) over time in Europe [153, Eurostat, 2001]

The highest per capita pig meat consumption both in terms of quantity and as a relative proportion of total meat consumption was recorded in 1999 in Denmark (65.8 kg/person of pig meat, compared to a total meat consumption of 117.8 kg/person). Similar levels of pig meat consumption per capita, although with slightly lower figures, are found in Germany, Spain and Austria. Spain has the highest overall consumption of meat in the EU, although it has been remarked that the annual 30 million tourists may contribute to this high amount. While Sweden and Finland have the lowest overall meat consumption in the EU (72 and 69 kg/person respectively), Greece (32 %) and UK (23 %) have the lowest proportional consumption of pig meat. [203, EC, 2001]

1.3.3 Economics of the pig sector

The economics of pig production are largely dictated by the availability of feed and access to suitable markets. This has led to regional development of the industry, for example in the Po valley, where pig production has developed in association with cereal growing and dairy production, and due to the easy access to transport.

More recently, environmental constraints have led to a link between production and the availability of land for the irrigation of effluent. Denmark has a definite advantage over pig producers in the Netherlands and several other countries in that its pig population is spread across the entire country, and thereby it has a low density of pigs in relation to land area. The Danish farm system generally combines pig production with mixed farming; allowing effluent to be used in a manner that lessens the environmental hazard. The association with mixed farming also provides benefits in terms of feed costs. A similar situation exists in the concentrated pig production areas in Germany, where pig production is associated with mixed farms, again facilitating a control of the feed inputs and irrigation of the effluent.

Pig density in Spain as a whole is very low, but there is a concentration of intensive pig farming and other agricultural activity in the northern Autonomous Communities (e.g. in Cataluña). There are still many areas where manure can be applied without a potential risk of water pollution by nitrates. It has been stated that the application of animal manure to land is of great agronomic interest to Spain as, along with the savings on chemical fertilisers, it can also improve the structure and fertility of most Spanish soils and can contribute significantly to the fight against desertification. These favourable circumstances support the growth of the sector and even the setting up of foreign companies. [89, Spain, 2000]

Generally, pig production in the EU does not tend to show the level of vertical integration found in the poultry sector, for instance the breeding and finishing of pigs are often carried out in separate facilities. In recent years there has been a tendency towards a more integrated approach with an individual or company based control of feed supply, pig production and slaughtering capacities. There is also a trend that even in situations where breeding and finishing are undertaken on separate sites, these may be owned by a single producer. The most developed integrated production systems are in Denmark, under the guidance of the Federation of Danish Pig Producers and Slaughterhouses (Danske Slagterier).

Few data have yet been submitted on the economic situation and profitability of the pig farming industry. Profitability data are needed to allow the determination of BAT. For this the profitability per sector and per country would be necessary to allow for differences between MSs (see Annex 7.6) to be accounted for.

Pig farming is typically characterised by periods of relatively high profits alternating with periods of negative margins. For Europe as a whole, prices have dropped and the scope for investments at the farm level has become more limited. Many farmers have adopted an attitude of waiting in anticipation for better times. In some countries (such as the Netherlands and the Flemish Region of Belgium) environmental problems have led to calls for fewer pig places and many farms are expected to close down. An increasing debate in some MSs is expected to put intensive livestock farming in general, and pig production in particular, under more pressure and some structural changes in the pig production sector are expected in the coming years.

Where investments are made, there are a variety of reasons why farmers might decide to invest in environmental techniques. Often, national legislation pushes them towards the application of certain techniques, but also the requirements of the large grocery retailers can affect the choice and operation of production techniques. Increasing attention is being paid to animal welfare issues, such as the use of straw and access to an outdoor area. It should be borne in mind that techniques applied under the scope of "animal welfare" legislation are not always associated with the best environmental performance.

The financial terms under which commitments have to be made and under which new techniques are purchased by farmers vary largely between Member States and even between regions within Member States. Two clear examples were reported. The Finnish agri-environmental support programme [125, Finland, 2001] gives assistance to farmers if they participate in a special programme that requires them to take certain actions to reduce the impact of farming activities on the environment; these actions might involve making certain investments, or taking measures, for instance to reduce fertiliser use. In Finland it is also possible to get financial assistance for investments, for example to build new manure storage (Farm investment aid). This assistance can be direct financial assistance, or a loan by a credit institution with interest support, or a government loan at reduced interest. [188, Finland, 2001]

A regional programme was set up by Emilia-Romagna (Italy) to push farmers into investing in techniques for better manure management [127, Italy, 2001]. This programme adopted, for instance, flushing systems with canals, equipment for solid separation of pig slurry, tanks for pig slurry and cages for layers equipped with belt and forced drying.

1.4 Environmental issues of intensive poultry and pig farming

Environmental issues have only been on the agricultural agenda for a relatively short period of time. It was not until the eighties that the environmental impact of intensive livestock farming really became an issue, although there was already an awareness of the contamination of soil due to excess manure application and of odour increasingly becoming an issue due to an increasing population in the rural areas.

One of the major challenges in the modernisation of poultry and pig production is the need to balance the reduction or elimination of the polluting effects on the environment with increasing animal welfare demands, while at the same time maintaining a profitable business.

Potentially, agricultural activities on intensive poultry and pig farms can contribute to a number of environmental phenomena:

- acidification (NH_3, SO_2, NO_x)
- eutrophication (N, P)
- reduction of ozone-layer (CH_3Br)
- increase of greenhouse effect (CO_2, CH_4, N_2O)
- desiccation (groundwater use)
- local disturbance (odour, noise)
- diffuse spreading of heavy metals and pesticides.

Increasing knowledge of the different sources responsible for these environmental phenomena has increased the attention paid to a number of environmental aspects associated with the intensive rearing of poultry and pigs. The key environmental aspect of intensive livestock production is related to the natural living processes, i.e. that the animals metabolise feed and excrete nearly all the nutrients via manure. The quality and composition of the manure and the way it is stored and handled are the main factors determining the emission levels of intensive livestock production.

From an environmental point of view, the efficiency with which pigs convert feed for maintenance, growth speed and breeding is important. The pigs' requirements will vary during different stages of their life, e.g. during the rearing and growth periods or during different stages of their reproductive life. To be sure that their nutritional requirements are always met, it has become customary to feed nutrients at levels in excess of the animals' requirements. At the same time, emissions of N into the environment can be observed which are partly due to this imbalance. The process of N consumption, utilisation and losses in the production of slaughter pigs is quite well understood (see Figure 1.17).

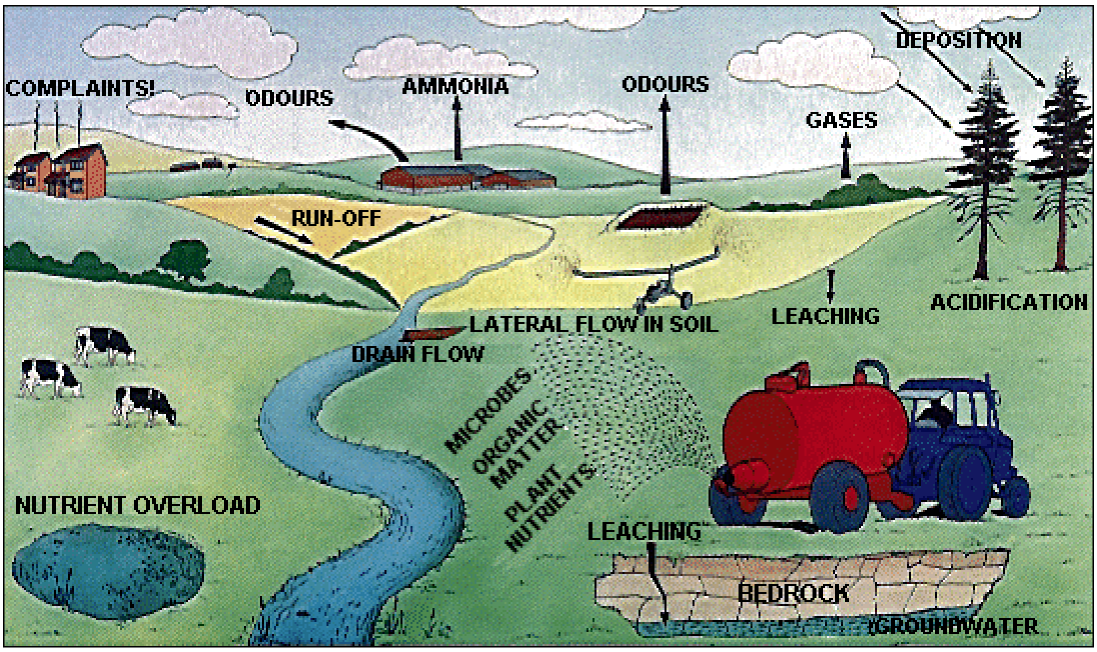

Figure 1.16: Illustration of environmental aspects related to intensive livestock farming [152, Pahl, 1999]

With research having started only relatively recently, many aspects are not known or quantified yet. Emissions are often diffuse and very difficult to measure. Models have been and still are being developed to allow accurate estimations of emissions to be made where direct measurements are not possible. Also, a number of aspects have only just been identified, where focus still is on emissions of ammonia (NH_3) and on emissions of N and P to soil, groundwater and surface water.

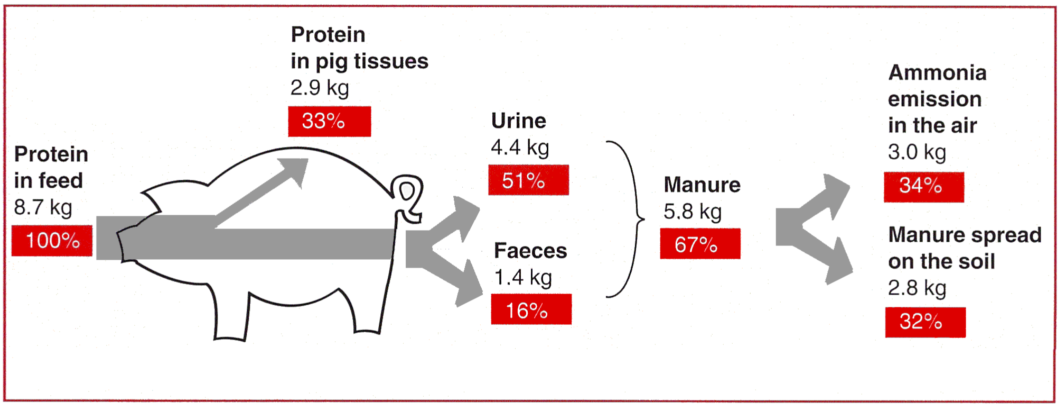

Figure 1.17: Consumption, utilisation and losses of protein in the production of a slaughter pig with a final live weight of 108 kg
[99, Ajinomoto Animal Nutrition, 2000]

1.4.1 Emissions to air

Air	Production system
Ammonia (NH_3)	Animal housing, storage of manure and landspreading of manure
Methane (CH_4)	Animal housing, storage of manure and manure treatment
Nitrous oxide (N_2O)	Animal housing, manure storage and landspreading
NO_x	Heaters in buildings and small combustion installations
Carbon dioxide (CO_2)	Animal housing, energy used for heating and transport on farm, burning of waste
Odour (e.g. H_2S)	Animal housing, storage of manure, landspreading of manure
Dust	Milling and grinding of feed, feed storage, housing of animals, solid manure storage and application
Dark smoke/CO	Burning of waste

Table 1.6: Emissions to air from intensive livestock production systems

N-related emissions

Most attention has been paid to the emission of ammonia from animal housing, as it is considered an important compound for the acidification of soils and water. A technical expert group is specifically working on the abatement of emissions of ammonia under the framework of the UNECE programme on long-range transboundary air pollution [9, UNECE, 1999].

Ammonia gas (NH_3) has a sharp and pungent odour and in higher concentrations can irritate the eyes, throat and mucous membranes in humans and farm animals. It slowly rises from the manure and spreads through the building and is eventually removed by the ventilation system. Factors such as the temperature, ventilation rate, humidity, stocking rate, litter quality and feed composition (crude protein) can all affect the ammonia levels. Factors that influence the rate of ammonia emission are presented in Table 1.7. For example in pig slurry, urea nitrogen represents more than 95 % of the total nitrogen in pig urine. As a result of microbial urease activity, this urea can rapidly be converted into volatile ammonia.

High ammonia levels also affect working conditions for the farmer and in many MSs workplace regulations set upper limits for the acceptable ammonia concentration in working environments.

Processes	Nitrogen components and appearance	Affecting Factors
1. Faeces production	Uric acid / urea (70 %) + undigested proteins (30 %)	Animal and feed
2. Degradation	Ammonia/ammonium in manure	Process conditions (manure): T, pH, A_w
3. Volatilisation	Ammonia in air	Process conditions and local climate
4. Ventilation	Ammonia in poultry house	Local climate (air): T, r.h., air velocity
5. Emission	Ammonia in environment	Air cleaning
Note: T: temperature, pH: acidity, A_w: water activity, r.h.: relative humidity		

Table 1.7: Schematic overview of processes and factors involved in ammonia release from animal houses

The generation of gaseous substances in the animal housing also influences the indoor air quality and can affect the animals' health and create unhealthy working conditions for the farmer.

Other gases

Much less is known about the emissions of the other gases, but some research is currently being carried out, in particular on methane and nitrous oxide. Increased levels of nitrous oxide can be expected from aerated liquid manure treatment processes, as well as with solid manure methods. The level of carbon dioxide resulting from respiration of the animals is proportional to the heat production of the animal. The carbon dioxide can accumulate in broiler houses if they are not properly ventilated.

Soil microbial processes (denitrification) produce nitrous oxide (N_2O) and nitrogen gas (N_2). Nitrous oxide is one of the gases responsible for the 'greenhouse effect', whilst nitrogen gas is harmless to the environment. Both can be produced from the breakdown of nitrate in the soil, whether derived from manure, inorganic fertilisers or the soil itself, but the presence of manure encourages this process.

Odour

Odour is a local problem but is an issue that is becoming increasingly important as the livestock industry expands and as ever increasing numbers of rural residential developments are built in traditional farming areas, bringing residential areas closer to livestock farms. The increase in farm neighbours is expected to lead to increased attention to odour as an environmental issue.

Odour can be emitted by stationary sources such as storage, and can also be an important emission during landspreading, depending on the spreading technique applied. Its impact increases with farm size. Dust emitted from farms contributes to odour transport. In areas with a high density of pig production, plumes from one farm can potentially transfer diseases to other farms.

Odour emissions especially from large poultry farms, can give rise to problems with neighbours. Emissions of odour are related to many different compounds such as, mercaptans, H_2S, skatole, thiocresol, thiophenol and ammonia [173, Spain, 2001].

Dust

Dust has not been reported as an important environmental issue in the surroundings of a farm, but it may cause some nuisance during dry or windy weather. Inside the animal house, dust is known under certain circumstances to be a contaminant that can affect both the respiration of the animals and the farmer, such as in broiler houses with high litter contents.

As an example, emissions of respirable dust (small dust particles) from deep litter systems (half litter, half slatted floor) and cage systems were estimated at 2.3 and 0.14 mg/h per hen respectively, based on measurements in commercial houses. Litter systems clearly give higher concentrations of respirable dust within the housing (1.25 and 0.07 mg/m^3 respectively). The differences can be explained in combination with the higher level of activity shown by hens in non-cage systems.

1.4.2 Emissions to soil, groundwater and surface water

Emissions from slurry storage facilities that contaminate soil and ground- or surface water occur because of inadequate facilities or operational failures and should be considered accidental rather than structural. Adequate equipment, frequent monitoring and proper operation can prevent leakage and spillage from slurry storage facilities.

Emissions to surface water can occur from a direct discharge of the waste water arising on a farm. Little quantified information is available on these emissions to surface water. Waste water arising from household and agricultural activities might also be mixed with slurry to be applied onto land, although mixing is not allowed in many MSs.

Waste water discharged directly into surface water can come from various sources but, normally only direct emissions from slurry treatment systems such as the lagoon systems are permitted. Emissions to surface water from these sources contain N and P, but increased levels of BOD may also occur; in particular in dirty water collected from the farmyard and from manure collection areas.

However, from all the sources, landspreading is the key activity responsible for the emissions of a number of components to soil, groundwater and surface water (and air, see Section 1.4.1). Although manure treatment techniques are available, the application of manure onto land is still the most favoured technique. Manure can be a good fertiliser, but where it is applied in excess to soil capacity and crop requirements it is a major agricultural source of emissions.

Soil and groundwater	Production system
Nitrogenous compounds	Landspreading and manure storage
Phosphorus	
K and Na	
(Heavy) metals	
Antibiotics	

Table 1.8: Main emissions to soil and groundwater from intensive livestock production systems

Most attention has been given to the emission of **nitrogen** and **phosphorus**, but other elements, such as potassium, nitrite, NH_4^+, micro-organisms, (heavy) metals, antibiotics, metabolics and other pharmaceuticals may end up in manure and their emissions may cause effects in the long run.

Contamination of waters due to nitrates, phosphates pathogens (particularly faecal coliforms and *Salmonella*) or heavy metals is the main concern. Excess application to land has also been associated with an accumulation of copper in soils, but EU legislation in 1984 significantly reduced the level of copper allowed in pig feeds, thereby reducing the potential for soil contamination when manure is correctly applied. While improved design and management can lead to elimination of potential pollution sources on site, the existing spatial density of pig production in the EU raises particular concern with regard to the availability and suitability of land for spreading pig slurry. Increased environmental regulation of spreading of manure has sought to address this problem. Indeed, in the Netherlands and the Flemish region of Belgium exports of surplus manure are now occurring.

Nitrogen

For nitrogen, the various emission routes are well illustrated in Figure 1.18. Through these reactions, losses of 25 – 30 % of nitrogen as excreted in pig slurry have been reported. Depending on the weather and soil conditions, this can be 20 – 100 % of the ammoniacal nitrogen if slurry is surface spread. The ammonia emission rate tends to be relatively high in the first few hours after application and decreases rapidly during the day of application. It is important to note that the ammonia release is not only an unwanted air emission, but also a reduction of the fertilising quality of the applied manure.

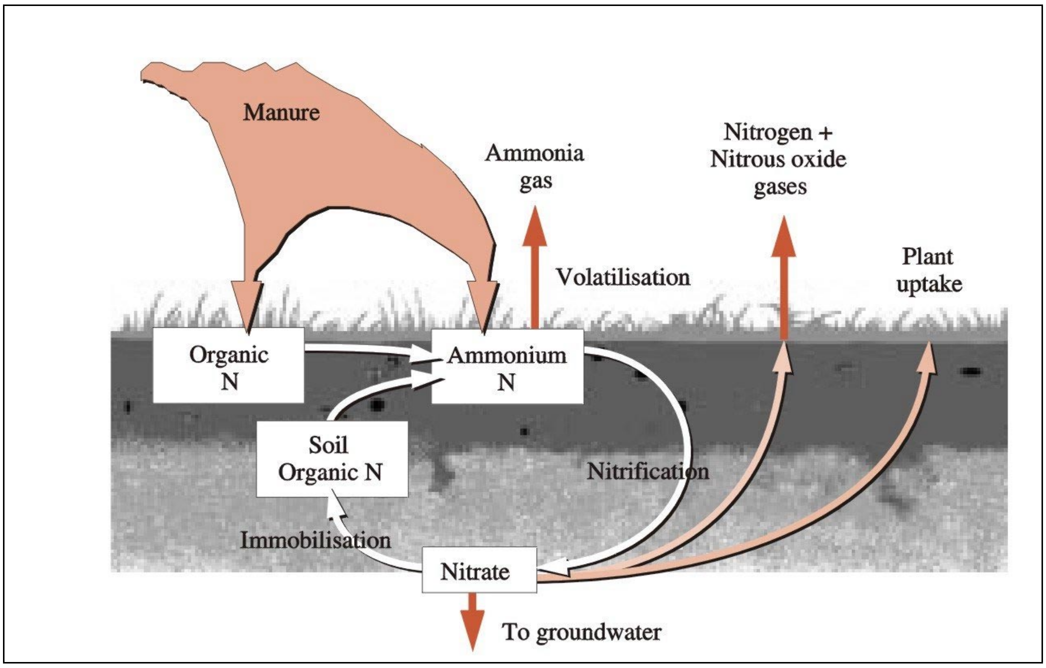

Figure 1.18: Nitrogen cycle showing the main transformations and losses to the environment [50, MAFF, 1999]

Pollution from agriculture, and in particular nitrogen pollution, has been identified through research evidence as posing a risk to the quality of European soil and surface and marine waters. The risks relate to the high level of nitrates found in drinking water, eutrophication of surface water (in synergy with phosphorus) and coastal waters and acidification of soils and waters. (Eutrophication involves excessive algal growth, and can lead to potential adverse effects on aquatic biodiversity or human uses of water)

The objective of the EU Nitrates Directive 91/676/EEC is to reduce these risks via a reduction and limitation of nitrogen application per hectare of arable land. Members States are obliged to identify zones, that drain into waters vulnerable to pollution from nitrogen compounds and that require special protection; i.e. the Nitrate Vulnerable Zones. In these zones landspreading is restricted to a maximum level of 170 kg N/ha per year. In 2000, the combined area of all Nitrate Vulnerable Zones covered 38 % of the total EU-15 land area [205, EC, 2001].

Fewer problems arise from landspreading in areas where sufficient land appropriate for application is available for the amount of manure that is produced. Intensive livestock production and related nitrogen pollution are concentrated in different countries and in various regions in the EU. Nitrogen surpluses are observed to be most critical on pig and poultry farms.

Phosphorus

Phosphorus (P) is an essential element in agriculture and plays an important role in all forms of life. In natural (i.e. unfarmed) systems, P is recycled to soil in litter and natural and vegetative residues, where it remains. In such ecosystems P is fairly efficiently recycled. However, in agricultural systems P is removed in the crop or the animal product and further P has to be imported to sustain productivity. As only part of the P is taken up by the soil (5 – 10 %) large amounts are applied in excess of what is needed, in addition to which increasing amounts of P-containing manure are added.

The importance of manure as a source of phosphorus has increased to the point at which it is estimated that 50 % of the input to EU surface waters from leaching and penetration into soil can be attributed to the application of animal manure. [150, SCOPE, 1997].

Concentrations of 20 – 30 micrograms P/l in lakes or slow rivers can cause water eutrophication, with the danger of a growth of toxic blue algae (cyanophytes) in fresh water, which are P limited [209, Environment DG, 2002]

1.4.3 Other emissions

Noise

Intensive livestock farming can generate other emissions such as noise and emissions of bioaerosols. Like odour, is of local problem, and disturbances can be kept to a minimum by properly planning activities. The relevance of this problem may increase with expanding farms and with the growth in rural residential developments in traditional farming areas.

Bioaerosols

Bioaerosols are important for the role they can play in the spread of diseases. The type of feed and feeding technique can influence the concentration and emission of bioaerosols. The feeding of pellets or mealy feed mixes via liquid feed systems and through the addition of feed fats, or oils in the case of dry feed systems, can reduce dust development. Mealy feed mixes are better when combined with oils as binding agents. Liquid feed installations are regarded as desirable. A dry feed system may only be implemented on the basis of automatic slop / raw slop feeders. The high quality of the raw materials can be ensured through dry harvesting and storage. This will then avoid, in particular, microbial and fungal contamination.

Regular cleaning of the housing equipment and all the housing surfaces will remove dust deposits. This regime is assisted by the all-in/all-out rotation method, as following the removal of all the livestock careful cleaning and disinfecting of the housing is necessary.

As a general rule, in non-litter housings less dust occurs than in the case of litter-based housings. In litter-based housings, care must be taken to keep the litter, clean and dry, under all circumstances, and free of mould/fungus. Low air velocities in the floor area can reduce the dust content in the air.

2 APPLIED PRODUCTION SYSTEMS AND TECHNIQUES

This chapter describes the major activities and production systems found in intensive poultry and pig production, including the materials and equipment used and the techniques applied. It attempts to present the techniques that are generally applied throughout Europe and to create a background for the environmental data presented in Chapter 3. It also describes those techniques that can serve as a reference or benchmark for the environmental performances of the reduction techniques presented in Chapter 4.

This chapter does not seek to give an exhaustive description of all existing practices, nor can it give a description of all combinations of techniques that may be found on IPPC-farms. Because of historical developments and climatic and geophysical differences, farms will vary in the kind of activities that are applied, as well as in the way in which these activities are carried out. Nevertheless, it should give the reader a general understanding of the common production systems and techniques applied in Europe in the production of poultry products and pig meat.

2.1 Introduction

Livestock production is concerned with the processing of feed into a form that is suitable for human consumption. The objective is to reach a high feed utilisation as well as to use production methods that do not cause emissions that are harmful to the environment or to people. In general, the production systems do not require highly complex equipment and installations, but they increasingly require a high level of expertise to properly manage all the activities and to balance the production aims with the animals' welfare.

Intensive livestock farms which have animal numbers within the IPPC size range are generally characterised by a high a degree of specialisation and organisation. Central to all activities is the rearing, growing and finishing of animals for meat and/or egg production. The essential part of all activities is the animal housing system. This system (see Sections 2.2 and 2.3) includes the following elements:

- the way the animals are stocked (cages, crates, free)
- the system to remove and store (internally) the produced manure
- the equipment used to control and maintain the indoor climate
- the equipment used to feed and water the animals.

Other essential elements of the farming system are:

- the storage of feed and feed additives
- the storage of manure in a separate facility
- the storage of carcases
- the storage of other residues
- the loading and unloading of animals.

Additionally, on egg-producing farms, the selection and packaging of eggs is quite common.

A number of activities can be part of the farming system, but these vary between farms for reasons such as the availability of land, farming tradition, or commercial interest. The following activities or techniques may be encountered on an intensive livestock farm:

- the application of manure on land
- the on-farm treatment of manure
- an installation for milling and grinding of feed
- an installation for the treatment of waste water
- an installation for the incineration of residues such as carcases.

Schematically, this can be illustrated as in Figure 2.1.

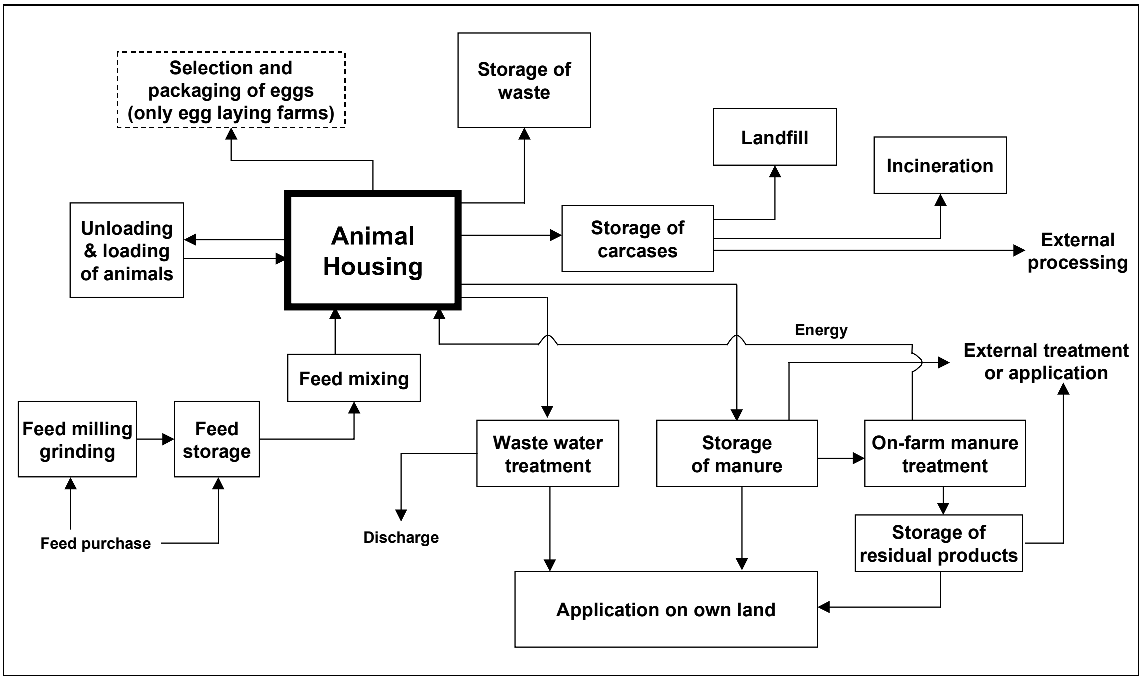

Figure 2.1: General scheme of activities on intensive livestock farms

2.2 Poultry production

2.2.1 Production of eggs

For commercial egg production, laying breeds are used that result from selection and breeding programmes that optimise their genetic potential for high egg production. Usually, they have small bodies that make them undesirable as meat producers. The smaller bodies benefit these breeds because very few nutrients are wasted in producing great body mass. Instead, they direct more of their dietary nutrients into egg-production. The egg producing breeds are further divided into birds that produce white shelled eggs or brown shelled eggs.

Laying birds kept in the commonly used laying cages have one laying period of about 12 – 15 months measured from the end of the growing period (around 16 – 20 weeks). The laying period can be extended if forced moulting is initiated between the 8th and 12th month of lay. This takes advantage of a second laying period that can add at least another seven months on the end of the forced moulting-period, taking the laying up to 80 weeks. [124, Germany, 2001]. In non-cage systems, the laying period lasts from about 20 weeks to 15 months, but no forced moulting is initiated.

The number of birds per surface area varies between housing systems. Where the commonly used cage systems allow a stocking density, depending on tier arrangement, of up to 30 – 40 birds/m^2 (corresponding to the available ground area) and severely restrict the birds in their freedom of movement, applied alternative systems have much lower densities of 7 birds/m^2 (littered floor) to 12 – 13 birds/m^2 (enriched cage). The limited space and the lack of structural design elements in the commonly used cages limit species-typical behavioural patterns and lead to damaged plumage, toe deformation and abnormal behaviour (cannibalism). However, cannibalism due to a lack of space can also be expected to occur in the enriched cage as well [194, Austria, 2001].

Most laying hens are still kept in batteries using cage systems, however, from January 2003, European legislation (Directive 1999/74/EC) will not allow the commonly used battery systems in new installations and by January 2012 these housing systems will have to be phased out completely. This means that from January 2012 only enriched cages will be allowed.

However, there are several studies and negotiations currently being undertaken to analyse the disadvantages of the installations defined by the above-mentioned Directive, and which take into account, amongst others, the health and environmental impact of the various systems. Depending on the results of these studies and negotiations it will be decided (in 2005) whether Directive 1999/74/EC will be reviewed. Until this decision is taken, uncertainty remains on the future requirements for cage-systems.

Currently an increasing number of non-cage systems in which the hens can walk around freely, such as free-range, semi-intensive, deep litter, barn and aviary are applied. From January 2002 the definitions of these systems will be changed by Directive 1999/74/EC into free-range and barn systems, where the term 'free-range' is used for housing systems in which the hens also have continuous daytime access to open-air runs. However, in the following sections the traditional terms are still used to describe the different non-cage systems, in order to avoid the terms barn and free-range being used out of the context of the above-mentioned Directive.

Design and management of non-cage systems is comparable with that of broiler systems (see Section 2.2.2).

2.2.1.1 Cage battery systems for laying hens

The battery systems can be described as a combination of the following elements:

- building construction
- cage design and placement and
- manure collection, removal and storage.

Intensive egg production usually takes place in closed buildings made of various materials (stone, wood, steel with sheet cladding). The building can be designed with or without a light system, but always with ventilation. The equipment in the housing can vary from hand operated systems to fully automated systems for indoor air quality control, manure removal and egg collection. Close to the housing or immediately attached are the feed storage facilities.

In cage systems, four major battery designs can be distinguished: flatdeck, stair-step, compact- and belt-battery (Figure 2.2). In addition to these, fully stepped designs are also available [183, NFU/NPA, 2001]. Constructions can have up to 8 levels or tiers and under current regulation this allows a stocking density of up to 30 – 40 birds per m^2, depending on the arrangement of the tiers. Rows of cages can be more than 50 m long, and with several corridors some of the modern large enterprises have buildings with 20000 to 30000 birds or more. Typical cages are 450 mm x 450 mm x 460 mm deep and house 3 to 6 birds. The cages are mostly made of steel wire and are equipped with installations for automatic watering (nipple drinkers) and automatic feeding (feed chain or carts) of the birds. Average occupancy of the housing is high (in the range of 311 – 364 days) with little time needed between laying cycles to clean the installation.

Cage floor inclination makes the eggs roll to the front side of the cages, where they are collected by hand or on a transport belt and removed for further selection and packaging. The bird droppings fall through the bottom of the cages at the back and are stored underneath or are removed by scrapers or belts. In general, flatdeck and stair-step cages need more space and require a larger investment per bird. Due to the way they are applied, these systems produce wetter manure and also account for a higher NH_3-emission than the other systems (concentrations 40 ppm in the cage area at low ventilation rates). No current application rates for the different cage systems are known, but it is believed that most of the laying hens in Europe are kept in compact or belt battery cage systems.

The droppings of laying hens in battery systems are not mixed with other material and can be managed in different ways, for example in some housing systems, water is added to allow easier transport of the slurry. Essentially, two different ways of collection and storage can be distinguished:

- housing with (temporary) manure storage in the cage area:
  - non-aerated manure
  - aerated manure
- separated cage area and storage facility.

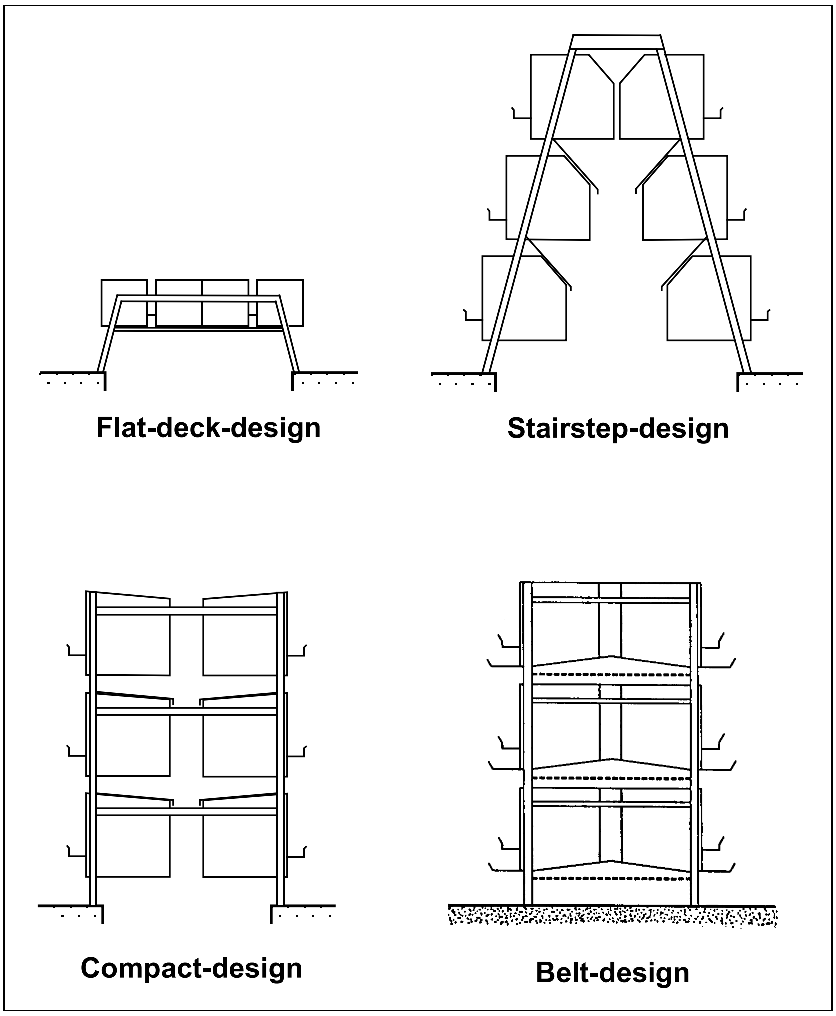

Figure 2.2: Four common battery designs for housing of laying hens
[10, Netherlands, 1999] and [122, Netherlands, 2001]

The dry matter of fresh laying hen droppings is about 15 – 25 % and drying means that dm-content can increase to 45 – 50 %. Drying to a higher dm-content may be possible to reduce emissions even further, but this requires more energy. Normally, dried manure (45 – 50 %) is removed from the housing for immediate application or transportation, or is stored on-farm in a separate storage facility. In the storage, the dm-content can further increase to about 80 % by natural drying (composting or heating). During this process, emissions of ammonia and odour will occur.

Where fresh manure is removed from the layer housing to a separate closed or open storage, drying occurs entirely naturally or, in the case of deep-pit houses, it can be done by forced ventilation of the storage area. It should be noted that with quick or immediate removal of the wet droppings, the emitting substance (at 15 – 25 % dm-content) has in fact been removed from the housing to the storage facility where further drying (and emission) takes place.

Amongst the many different combinations that exist, four commonly applied battery systems for laying hens in Europe can be distinguished:

- battery system with open manure storage under the cages
- deep-pit and canal houses
- stilt houses
- manure belt system with external storage.

2.2.1.1.1 Battery system with open manure storage under the cages

The layers are housed in cages in one or more tiers. The cages (flatdeck, stair-step or compact-battery) are equipped with plastic flaps or metal plates on which the droppings remain for a while. Depending on the design, droppings may fall into the manure pit by themselves or be removed by a scraper. The droppings (and the spilled water from the drinkers) are collected in a manure pit underneath the cages and, once a year or less frequently, are removed by a scraper or a front loader [26, LNV, 1994], [122, Netherlands, 2001].

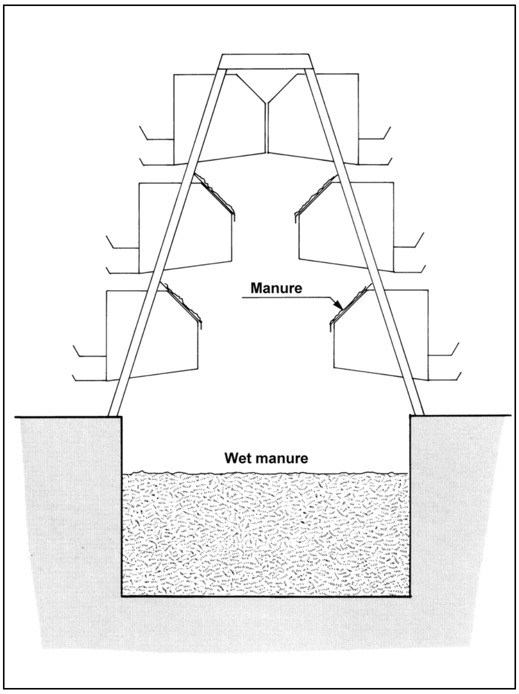

Figure 2.3: Example of open manure pit under a stair-step battery
[10, Netherlands, 1999]

2.2.1.1.2 Battery systems with aerated open manure storage (deep-pit or high-rise systems and canal house)

The cages are positioned above the manure storage pit. The height of a deep-pit system measures between 180 and 250 cm. The canal house has a pit, which measures approximately 100 cm. The wet droppings fall in the pit and remain there for periods of up to a year or more.

In a deep-pit house as well as in a canal house, fans that are placed below the cages in the lower part of the building draw in ventilation air. The air is drawn into the building through the roof (open ridge system) and passes the cage area, where it is warmed up. The warm airstreams then pass over the manure stored in the pit and leave the house. The manure that is stored in the pit is dried by this flow of warm air.

During storage, heating by fermentation occurs. This fermentation results in a high ammonia emission level. To get a good drying result the manure on the plates underneath the cages should be pre-dried for about 3 days. After 3 days the manure has a dry material content of about 35 – 40 %. [10, Netherlands, 1999]

In the past in the UK, a slat manure drying technique was applied to deep-pit houses with fully stepped and flatdeck systems. It left manure drying in steep sided cones for 6 months, after which the manure was dropped into the deep pit and the slats reset for the rest of the year. This technique may still be applied, but has largely fallen out of use with the demise of most fully stepped and flatdeck cages in deep-pit systems [119, Elson, 1998].

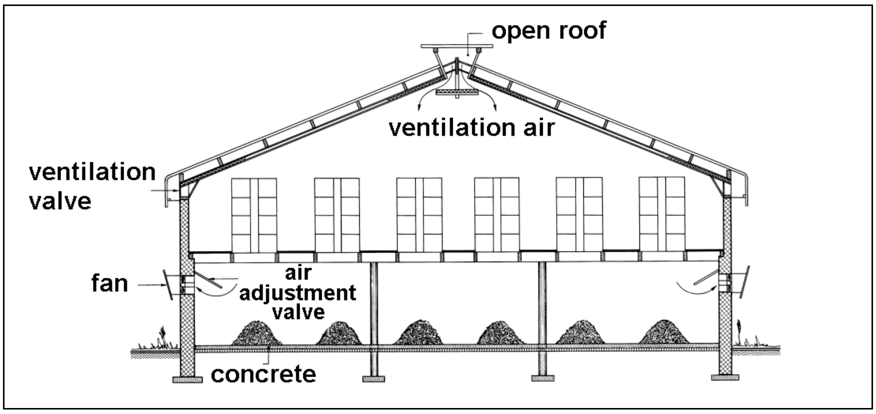

Figure 2.4: Deep-pit system for laying hens
[10, Netherlands, 1999]

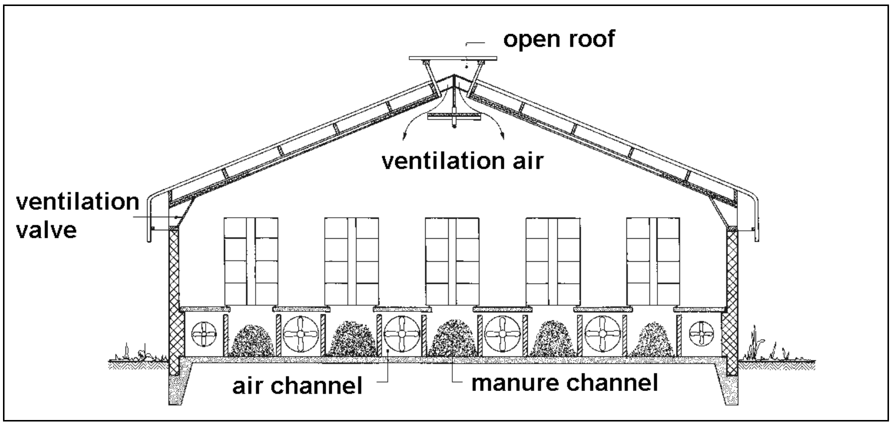

Figure 2.5: Example of a canal system for laying hens
[10, Netherlands, 1999]

2.2.1.1.3 Stilt house system

A variation on the design of the deep-pit or high-rise system is the stilt house. It combines vertically tiered centre slot cages with scrapers under *all* tiers and an open deep-pit storage. The stilt technique employs a variable valve between the cage and the manure storage areas and has large openings in the manure store walls to enable the wind to pass through and assist drying. Thus, unlike the deep-pit system where manure storage and livestock areas are in the same place, in the stilt system they are separate. Therefore, manure can be removed from the store at any convenient time since it is out of sight and sound of the hens [119, Elson, 1998].

A stilt house can be considered similar to the deep-pit house in Figure 2.4, but without sidewalls.

2.2.1.1.4 Battery system with manure removal by way of scrapers to a closed storage

This system is a variation of the open storage system applying cages over a shallow open manure channel that is as wide as the cages. Manure produced by the birds drops on to a plastic flap or a plate under the cages. From here, the manure goes into the manure channel. The manure is removed on a regular basis (daily or weekly) and stored in a separate storage facility (pit or shed). The pit is usually made of concrete. Using a scraper, after several years the pit floor becomes rough and a film of manure remains on the floor, increasing the emissions of ammonia. Both the manure on the plastic flaps or plates and the manure film on the floor cause a lot of ammonia emissions [10, Netherlands, 1999], [26, LNV, 1994], [122, Netherlands, 2001].

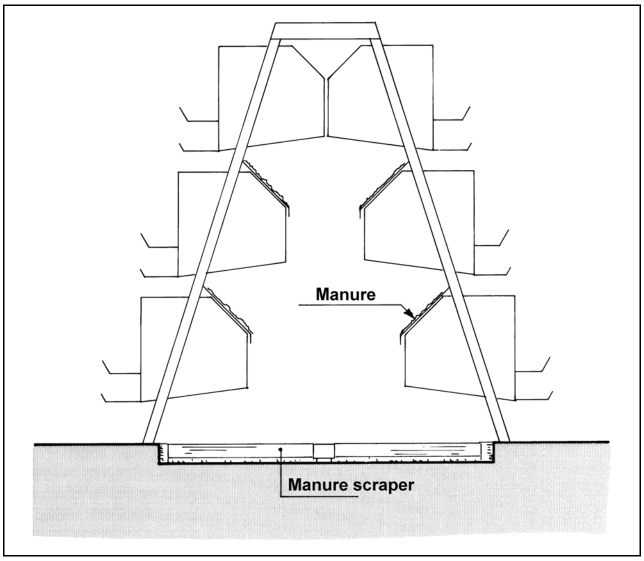

Figure 2.6: Example of open manure channel with scraper under a stair-step battery [10, Netherlands, 1999]

2.2.1.1.5 Manure-belt battery with frequent removal of manure to a closed storage with or without drying.

The manure-belt battery is commonly applied throughout Europe. In this system the laying hens' manure is collected on manure-belts below the cages and transported to a closed storage at least twice a week. The manure is collected on manure-belts that are situated under each tier (or cage level). At the end of the belt a cross conveyor transports the manure further to the external storage. The manure-belts are made of smooth, easy-to-clean polypropylene or trevira and no residue sticks to these belts. With modern reinforced belts, manure can be removed from very long runs of cages. Some drying takes place on the belts, especially in summer conditions, and manure may be held on the belts for up to a week.

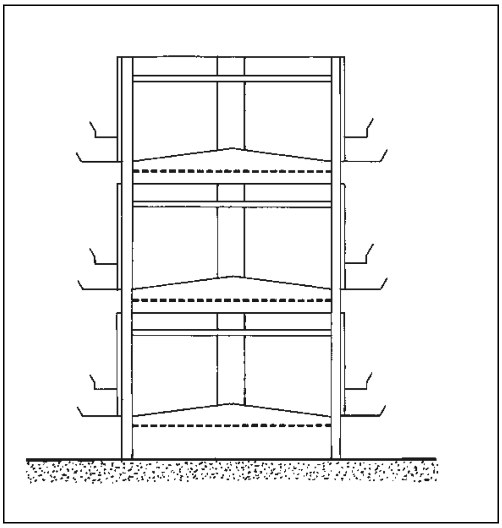

Figure 2.7: Example of a manure-belt battery (3 tiers) with a belt under each tier to remove manure to a closed storage
[10, Netherlands, 1999]

In improved belt systems, air is blown over the manure to achieve faster drying of the manure. The air is introduced just under each tier of cages, usually via rigid polypropylene ducts. Another benefit is the introduction of fresh cooling air immediately adjacent to the birds. Further improvements consist of the introduction of pre-warmed house air and/or the use of heat exchangers to pre-warm incoming outside air.

2.2.1.1.6 Enriched cage

A very recently developed housing regime for layer birds is the enriched cage. It should be used as a replacement for the hitherto commonly used cage systems: see Section 2.2.1 where the phasing out of the commonly used cage systems is described. Some minimum requirements have been established in the EU Directive including provisions, such as that: each cage must be equipped with perches, laying nest and a sand bath with litter material. [121, EC, 2001].

Depending upon the individual systems manufacturer, designs may differ in the number of birds per cage, the nest, the sand bath design and the arrangement within a cage. Generally, birds are kept in a groups of 40 and more [179, Netherlands, 2001]. Compared with the commonly used cage, it offers more space and is equipped with structural features to stimulate species-specific behaviour. In addition litter, sand, shavings, or other materials are used.

The presence of litter in the cage is one of the main factors that affects management, i.e. issues related to the type of litter material, the filling and removal of the litter surface (automated or not) and the risk of increased levels of dust in the building. There is also an increased risk that eggs that are laid in the litter material are removed with the manure. The selection of the litter material is very important, and depends on its cost, availability, use by birds, and easy removal and disposal. The amount and cost of litter for each laying hen per day is very variable and depends on the material used. It is expected that the litter material will increase the manure volume, so its value as a fertiliser may be affected, as will the processing of the manure after its removal from the building. These aspects can be very different depending on the type of litter material. [204, ASPHERU, 2002]

The cages are made of steel wire with horizontal front meshing or rods and solid partitions arranged in tiers of 3 and more. Manure is removed automatically via manure-belts (with or without belt aeration).

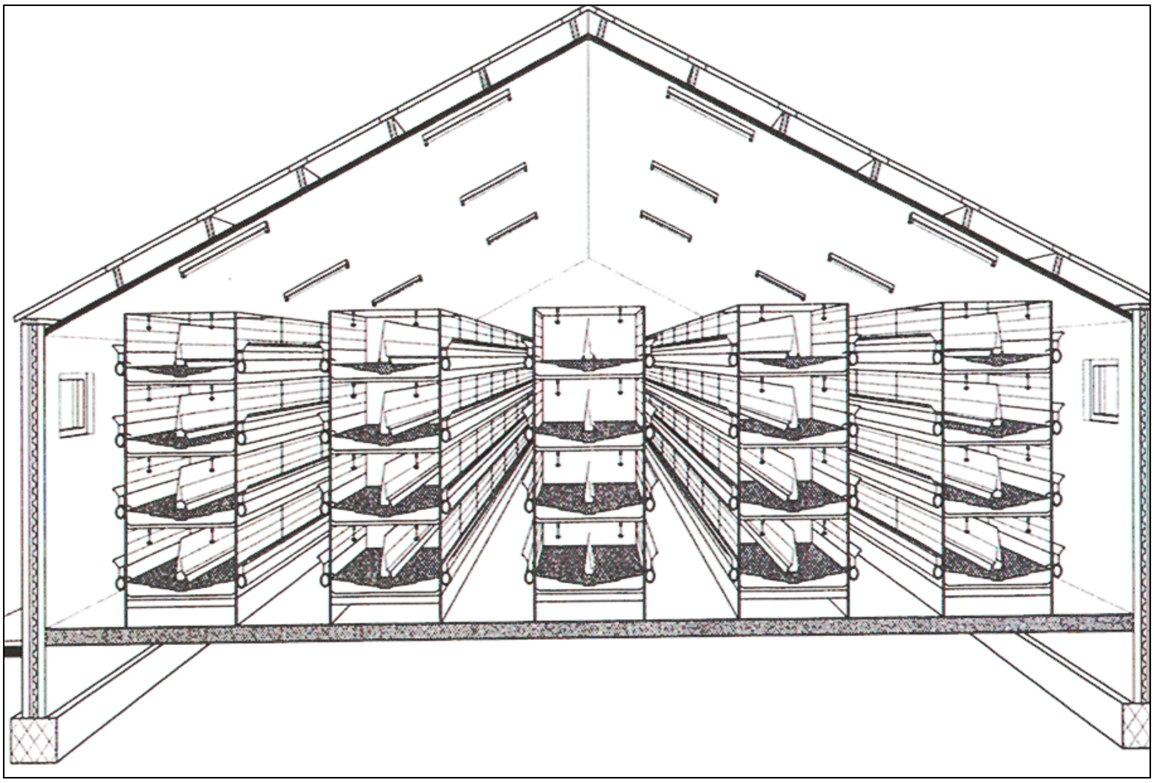

Figure 2.8: Schematic picture of a possible design of an enriched cage
[128, Netherlands, 2000]

A typical emission is reported as being 0.035 kg NH_3 per bird place per year (NL). Ranges have been reported of 0.014 – 0.505 kg NH_3 per bird place per year (D) associated with a rate of approximately 160 grams fresh droppings (of 1.3 % N content) produced per bird per day. The reported dry matter content of the manure is 20 – 60 % depending on the system applied: manure-belt without drying 25 – 35 %, and the aerated belt 35 – 50 %.

The energy required for belt operation and ventilation is comparable to that of other (aerated) belt systems. The use of litter can cause more dust inside the housing. Materials such as sand, shavings or others needs to be disposed of.

Feeding and watering, lighting and ventilation of this system are very similar to the commonly used cage, but in addition 1 – 2 kg litter per birdplace per year is required.

This system is intentionally designed as an alternative to the commonly used cage systems. As such the application would not require substantial changes to the building, but it will require a full replacement of the cages in existing systems.

Total operational costs have been estimated at EUR 1.5 per bird per year (NL).

Nowadays enriched cages are implemented in only a few farms under commercial conditions, for example, in the Netherlands (reference year 2001) only 1 farm applies this system.

Reference literature: [122, Netherlands, 2001], [124, Germany, 2001] [180, ASEPRHU, 2001] [179, Netherlands, 2001] [204, ASPHERU, 2002]

2.2.1.2 Non-cage housing systems for laying hens

Laying hens are also kept in non-cage housing systems. What these housing systems all have in common is that the birds have more space or can move around more freely within the building. The housing construction in which the birds are kept is similar to that of the cage systems. Various designs are applied in different Member States, such as:

- the deep litter system
- the aviary system.

In Directive 1999/74/EC two non-cage systems are defined: the barn and the free-range system.

2.2.1.2.1 Deep litter system for laying hens

The layer house is a traditional building with respect to walls, roof and foundation. Thermally insulated poultry houses have forced ventilation; either windowless or with windows for natural daylight. Birds are kept in large groups with 2000 to 10000 bird places per housing facility.

The air is replaced and emitted passively by natural ventilation or by forced ventilation with negative pressure. In accordance with EU Egg Marketing Standards currently in effect, at least one third of the floor area (concrete floor) must be covered with bedding (chopped straw or wood shavings used as litter material) and two thirds arranged as droppings (manure) pit.

The pit is covered with slats that are mostly made of wood or artificial material (wire meshing or plastic lattice) and slightly raised. Laying nest, feed installation and the water supply are placed on the slats to keep the litter area dry. The manure is collected in a pit below the slats during the laying period (13 – 15 months). The pit is formed by the raised floor or can be sunk into the ground (Figure 2.9).

Automatic supply of feed and drinking water, with long troughs or automatic round feeders (feeder pans) and nipple drinkers or round drinkers are installed above the pit area. Droppings are removed from the pit at the end of a given laying period; or intermittently, with the aid of (aerated) manure-belts. At least one third of the used-air volume stream is drawn off via droppings pit. Individual or community nests are provided for laying; automatic egg collection is also possible. Lighting programmes to influence performance/rate of lay and crude protein-adapted feeding may be applied. [128, Netherlands, 2000], [124, Germany, 2001]

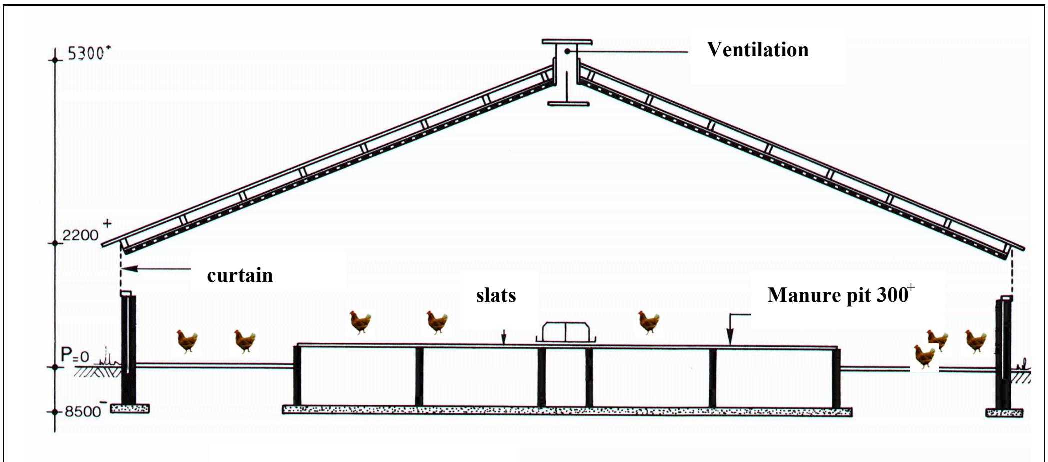

Figure 2.9: Schematic cross-section of traditional deep litter system for layers [128, Netherlands, 2000]

2.2.1.2.2 Aviary system (perchery)

This poultry house is a construction with thermal insulation and forced ventilation, either windowless, or with windows for natural daylight and artificial light for applying lighting programmes; houses can be combined with range and outside scratching area. Birds are kept in large groups and enjoy freedom of movement over the entire house area. Housing space is subdivided into different functional areas (feeding and drinking, sleeping and resting, scratch area, egg laying area). The birds can use several house levels that allow for higher stocking densities compared to the commonly used floor regime (deep litter). Droppings are removed via manure belts into containers, or into a manure pit, or otherwise collected in a manure pit. Litter is spread onto a fixed concrete area. Feed (mostly feed chains) and drinking water (nipple or cup drinkers) are automatically supplied. Laying nests (individual or community nest design) have manual or automatic egg collection.

Stocking density is maximised to 9 birds per usable m^2 or to 15.7 birds per ground surface (in m^2), with houses accommodating between 2000 and 20000 birds (bird places).

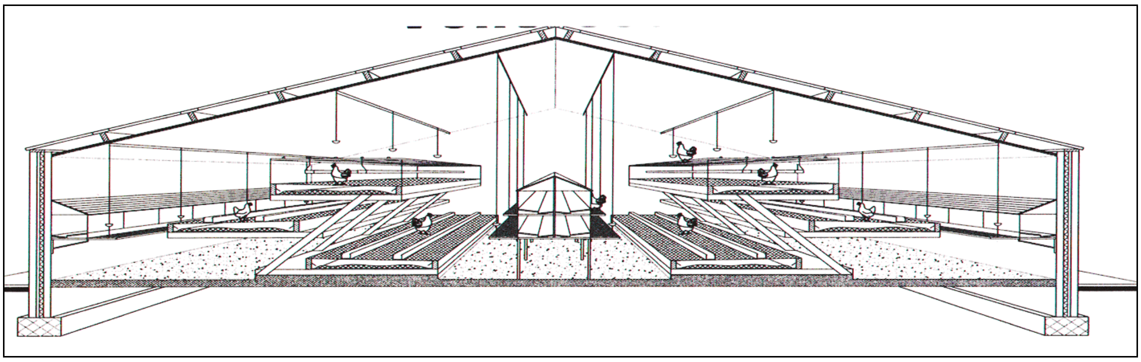

Figure 2.10: Schematic picture of an aviary system
[128, Netherlands, 2000]

2.2.2 Production of broiler meat

Broiler meat is produced by growing meat-type breeds of chicken, which in reality are hybrid varieties of combinations of many different breeds. The combinations of breeds are selected to produce a variety (strain) with meat characteristics that the producer desires most. Some breeds grow faster and larger while others emphasise traits like larger breast meat yield, more efficient feed conversion or more disease resistance. Strains are often named after the breeding companies that genetically develop them. Obviously, these strains are not as well suited to laying eggs as the laying breeds.

The traditional housing of intensive broiler production is a simple closed building construction of concrete or wood with natural light or windowless with a light system, thermally insulated and force-ventilated. Buildings are also used that are constructed with open sidewalls (windows with jalousie-type curtains); forced ventilation (negative pressure principle) is applied by way of fans and air inlet valves. Open houses must be located so that they are freely exposed to a natural stream of air and are positioned at a right angle to the prevailing wind direction. Additional ventilating fans operate via ridge slots, and gable openings may apply. This is intended to provide the in-house broiler area with extra air circulation during hot spells in summer. Mesh wire screens along upper sidewalls keep wild birds out.

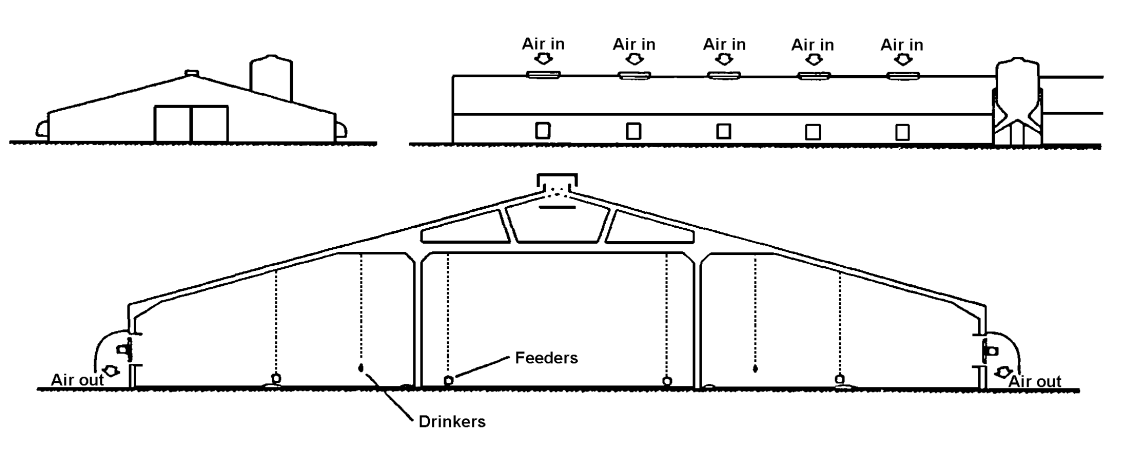

Figure 2.11: Example of schematic cross-section of a commonly applied broiler house [129, Silsoe Research Institute, 1997]

Closed buildings have oil- or gas-fired warm-air blowers for total room heating; radiant heaters are used for zonal heating in houses built for open-air ventilation. Artificial lighting and/or artificial/natural daylight combination lighting system are provided as required.

Broilers are kept on litter (chopped straw, wood shavings or shredded paper) spread over the entire house floor area which, in turn, is built as a solid concrete slab. Manure is removed at the end of each growing period. Automatic, height-adjustable feeding and drinking systems (mostly tube feeders with round feeder pans and nipple drinkers with drip water catch bowls) are applied. Crude protein-adapted feed is given. Broilers are kept at a stocking density of 18 to 24 birds per m^2. Stocking density is also measured in kg live weight/m^2 (e.g. in Finland), but this number is variable. New legislation is expected to limit the stocking density of broilers. Houses can stock between 20000 and 40000 birds.

2.2.3 Other poultry production sectors

2.2.3.1 Production of turkeys

Turkeys are kept for meat production and different production systems apply. It can be a two-age system (UK, Netherlands). The first period covers a breeding period for all birds up to 4 – 6 weeks. Than the stags (males) are shifted to a different housing. The breeding period is 19 – 20 weeks with an average slaughter weight for the stags of 14.5 kg (21 – 22 weeks) and for the hens of 7.5 kg (16 – 17 weeks) (see also Table 1.1). In Finland, four ages are distinguished relating to four different feeding rations, with stags being reared for 16 weeks and the hens for 12 weeks. The animals are kept in much higher densities at the start, when they are still small. During the growing period, the birds are thinned and after 22 weeks only a third of the birds may be left. For example in the UK, the hens are removed first and sold as oven ready birds. Stags are used for further processing.

2.2.3.1.1 Commonly applied housing systems

The commonly applied turkey housing is a traditional housing construction, which is very similar to the housing of broilers (Figure 2.11). Turkeys are housed in closed, thermally insulated buildings with forced ventilation, or (more frequently) in open (outdoor-climate) houses with open sidewalls and jalousie-type curtains (unrestricted natural ventilation). Forced ventilation (negative pressure) is applied by fans and inlet valves. Free open-air ventilation is created via automatically controlled jalousies or wall-mounted inlet valves. Open houses are aligned at right angles to the prevailing wind direction and located in such a way as to be exposed to natural airflow. Additional ventilation is applied via ridge slots and gable openings. Radiant gas heaters are applied for heating.

Precautions are put in place to protect against emergencies like power cuts, extreme weather conditions or fire, as per unit a large number of birds will always be at risk. During peak summertime temperatures, additional measures are taken to minimise heat stress on the birds (by providing for larger-volume air change, operating extra fans for bird comfort in open houses, water fogging or roof sprinkling)

Wire meshing in the upper sidewall section is applied to keep wild birds out. A floor regime is operated with litter material (chopped straw, wood shavings) spread over the entire house floor area (built of concrete) with layers up to 9 – 12 inches deep. Manure removal and cleaning of the house takes place at the end of each respective growing period. All litter is removed by an excavator or frontloader. Litter replenishment is applied as needed. Automatic height-adjustable round drinkers and feeders are applied during the growing/feeding period. Daylight length and light intensity can be controlled during brooding and, in closed houses, over the entire brooding/finishing period.

In the following Sections 2.2.3.1.2 and 2.2.3.1.3, possible variations to the commonly applied system are described.

2.2.3.1.2 Closed house system

In this system, wood shavings/sawdust are taken out of the turkey house nine times during the fattening period. This reduces ammonia emissions because the temperature of the litter, together with the droppings, will not increase. The turkey house is similar to the standard as described in Section 2.2.3.1.1. The manure is taken out by means of a tractor with a loading shovel, while the drinking and feeding systems are lifted out of the way.

At the start of the production period a thin layer of wood shavings/sawdust (4 cm) is spread evenly on the floor. After 35 days all the manure is taken out of the house. A fresh layer of 3 cm (instead of 4 cm) of wood shavings/sawdust is provided. This pattern is repeated, at different intervals, until the end of the fattening period, as follows: after 35, 21, 21, 14, 14, 14, 14, 14 and 14 days respectively a 4, 3, 3, 3, 3, 3, 5, 5, (end) cm layer of wood shavings/sawdust are applied. During manure removal the birds are quietly moving away from the shovel. Behind the shovel a system is constructed for spreading the wood shavings/sawdust.

The ammonia emission from this system is estimated at 0.340 kg NH_3 per turkey place per year, but more research is needed to validate this. For this, a new measuring system will be installed in a turkey house to provide NH_3 emission measurements twice a day.

Compared to the commonly used systems (Section 2.2.3.1.1), in which farmers mix the manure several times during the fattening period, no high-energy input is needed. Due to the high dry matter content, compared to the traditional systems, the handling of the manure (e.g. palletising) is easier and also requires less energy.

There is a lot more dust in the house, because of the dry manure and the spreading of a mixture of wood shavings and sawdust (up to 65 %). Farm workers should use face masks. It is clear that labour costs would rise. There is also a question over whether the frequent mucking-out of the housing could affect turkey growth performance.

This system is a management system and does not require any alterations to the housing system. It can be applied in new and existing houses. In existing houses, provisions only have to be made for (semi-) automatically lifting of the feeding and drinking systems.

The investment costs are slightly higher than that of the traditional system. With these systems a farmer also needs regular use of a tractor or a shovel. Labour costs will be increased with the frequent mucking-out. Investment costs are reported to be EUR 6.36 per bird place. Total operational costs are around EUR 0.91 per bird place per year.

In the Netherlands, 1 turkey house (10000 turkeys) is currently applying this system.

Reference literature: [128, Netherlands, 2000]. An application leaflet is available by Koudijs-Wouda (turkey feedmill organisation)/Agramatic/Bureau TES (These are respectively a turkey feed plant, Agriculture Design Office and Advisory service for NH_3 emissions)

2.2.3.1.3 Partially ventilated littered floor system

A partially ventilated floor is designed to reduce the emission of ammonia in a commonly used turkey housing. About 75 % of the total floor surface is littered and 25 % consists of a raised platform with slats. The raised platform is about 20 cm above the concrete floor and covered with a nylon cloth. On both the concrete floor and the nylon cloth there is a layer of wood shavings. A fan blows air through the raised floor and the wood shavings into the house.

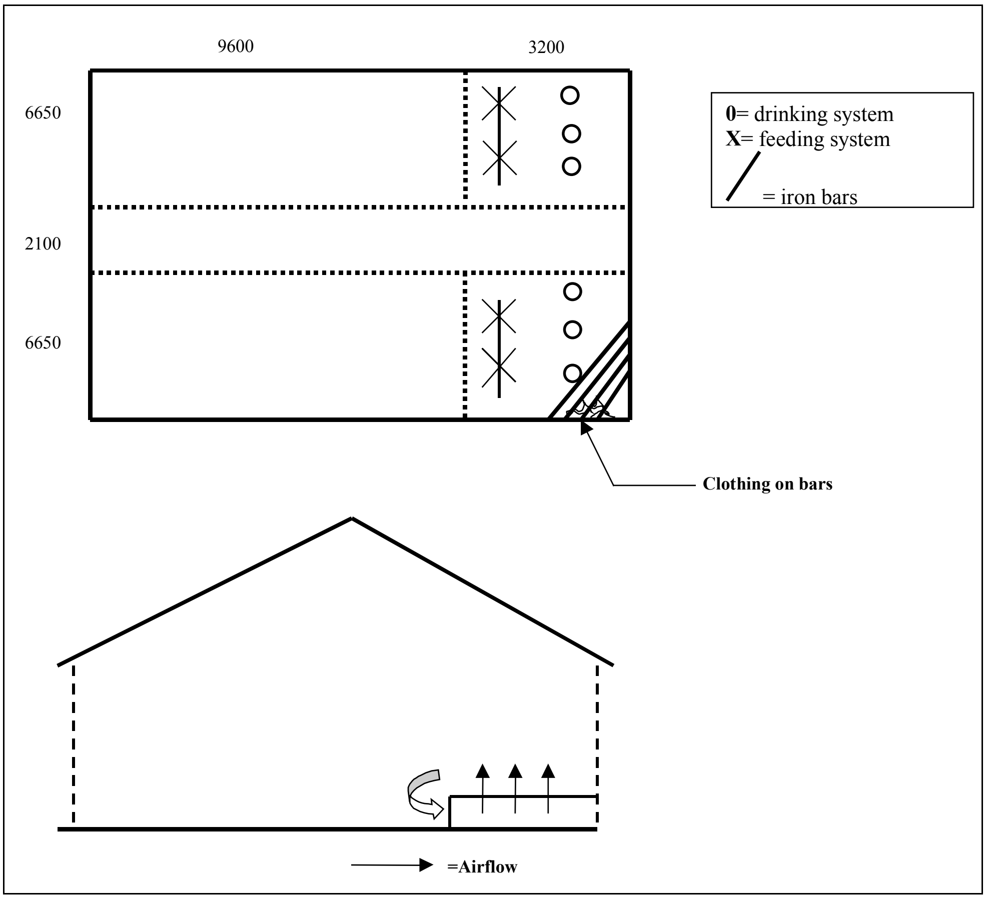

Figure 2.12: Schematic cross-section of the partially ventilated litter floor system for turkeys [128, Netherlands, 2000]

This system reduces ammonia emissions by 47 % compared with the reference system, i.e. reducing the emission to 0.360 kg NH_3 per turkey place per year. However, compared to traditional systems, a high energy input is required for ventilation. The measured dust concentrations are high, therefore it requires the use of a device for respiratory protection. Due to the high dry matter content, compared to the traditional systems, the handling of the manure (e.g. palletising) is easier and needs less energy.

The birds will feed and defecate on top of the platform, where the drinkers and feeders are placed. At the beginning of the trial 5 kg/m^2 woodshavings are spread on the concrete floor and 2 kg/m^2 on the platform. During the production cycle, the quality of the litter may require application of more woodshavings. The ammonia emission is reduced by drying some of the litter.

This system can be applied to new and existing houses, as they do not need much alteration. It is questionable whether it is applicable under animal welfare regulations. Considering the weight of the birds, application is considered to be difficult. Also, the cloths covering the slats tore during the trials, which caused sub-optimal air movement.

The extra investment costs will be higher than for the traditional systems and are estimated at EUR 6.36 per bird place (EUR 20 per kg NH_3). Annual operational costs are about EUR 2 per bird place per year (EUR 2.9 per kg NH_3).

In the Netherlands, there is only 1 farm applying this system [181, Netherlands, 2002].

Reference literature: [128, Netherlands, 2000] [181, Netherlands, 2002]

2.2.3.2 Production of ducks

Ducks are generally kept for meat production. There are numerous breeds on the market, but popular breeds for commercial meat production are Pekin and Barbary; Rouen and Muscovy are both Barbary breeds. Different breeds are used for egg-laying, although Pekins have a reasonable laying performance compared with the other meat types. The Muscovy ducks are the heavier types. Drakes are normally heavier than ducks. As with chickens, the meat types are more heavily built than the egg type birds (Table 2.1).

Ducks are kept in housing, although in some Member States outdoor rearing is also allowed. There are three main housing systems for fattening of ducks:

- fully littered, with a water system positioned above a gully
- partly slatted/partly litter
- fully slatted.

The commonly applied duck house is a traditional housing system and is similar to the broiler house (Figure 2.11). It has a concrete floor that is covered with litter. The house is equipped with a ventilation system (natural or mechanical) and, depending on the climatic conditions, heating is applied.

Meat type	Adult drake (kg)	Adult duck (kg)
Pekin	4.00 – 4.50	3.50 – 3.75
Muscovy	4.50 – 5.50	2.25 – 3.00
Rouen	4.50 – 5.00	3.50 – 4.10
Egg type		
Indian Runner	2.00 – 2.25	1.60 – 2.00
Khaki Campbell	2.25	2.00

Table 2.1: Range of weights of meat and egg production duck breeds
[171, FEFANA, 2001]

Production cycles will vary between Member States. In Germany, the production cycle for duck meat production is divided into a growing period up to day 21 followed by a finishing period until day 47 – 49. Rearing and growing is done in separate stalls. Manure is removed and the stalls are cleaned and disinfected during a service period of about 5 to 7 days before they are stocked again. Stocking density is 20 kg live weight/m^2 accessible floor area in both phases, with accessible areas typically measuring 16 x 26 m for growing and 16 x 66 m for finishing. Thus, the growing stalls can house approximately 20000 young ducks and the finishing stalls about 6000 ducks (See fact sheets in [124, Germany, 2001]).

Commonly applied is the fully littered system using wheat or barley straw or wood chips. The layer is usually not too thick because the manure of ducks is much wetter than that of chicken broilers. Slats, if applied, are usually of plastic-coated wire, wood or synthetic material.

2.2.3.3 Production of guinea fowl

No specific information is available on the production of Guinea fowl in Europe. The general picture is that this sector is quite insignificant compared to the production of other poultry species described above. Commercial breeding and raising of guinea keets can be compared with that of turkeys. Guinea fowl is very different in its behaviour from chicken and needs a lot of space. Somewhat dated information from US breeders and from the US Department of Agriculture (USDA) shows that Guinea breeding stock is generally housed in free-range systems. During the laying period the breeders are kept confined in houses equipped with wire floored sun porches. It is an open question whether there are any farms in Europe rearing Guinea fowl intensively in such numbers as to be under the scope of IPPC.

2.2.4 Control of poultry housing climate

For all poultry species, housing systems are equipped to maintain the indoor climate, but for broilers in particular climate control has been studied extensively. Factors that are important for the climate in poultry housing in general are:

- indoor air temperature
- air composition and air velocity at animal level
- light intensity
- dust concentration
- stocking density
- insulation of the building.

Adjustment is usually done by controlling the temperature, ventilation and illumination. Minimum health standards and production levels impose requirements on the indoor climate of poultry houses.

2.2.4.1 Temperature control and ventilation

Temperature control: Temperatures in the poultry house are controlled by means of the following techniques:

- insulation of the walls
- local heating (deep litter systems) or space heating
- direct heating (infrared, gas/air heating, gas-convectors, hot air cannon)
- indirect heating (central heating-space, central heating-floor)
- cooling by spraying of the roof (practised in warmer climates and in summer).

Floors of housing are often made of concrete and are normally not further insulated. Partly insulated floors are sometimes applied (e.g. Finland). There is a potential loss of heat from the housing by radiation to the soil underneath, but this is small and has not been reported as having an effect on the animals’ production.

Heating is sometimes applied through heat recovery from exhaust air, which is also used for manure drying. For layers, heating is hardly needed when the stocking density in the cages is high.

Generally, in winter, but also during the early stages of production (young birds) heating is applied to broilers. The capacity of the heating equipment is related to the number of birds in the shed and the volume of the shed. For example, in Portugal gas radiators with a capacity of 6000 kJ equal 650 new born birds per radiator and a capacity of 12500 kJ equals 800 new-born birds. Some typical temperatures for the housing of broilers are shown in Table 2.2. Movement is sometimes restricted when the birds are small to keep them near the brooders.

Ages (days)	Required heating (ºC)	Indoor environment temperature (ºC)	
	Source 1)	Source 1)	Source 2)
1 to 3	37 – 38	28	30 – 34
3 to 7	35	28	32
7 to 14	32	28	28 – 30
14 to 21	28	26	27
Adults	No heating	18 – 21	18 – 21

Table 2.2: Example of required indoor temperatures for broiler housing
Source 1): [92, Portugal, 1999], Source 2): [183, NFU/NPA, 2001]

In turkey housing, the required temperature is higher (32 ºC) at the beginning of the rearing period so heating may need to be applied. When the birds grow, the required ambient indoor-temperature is decreased to 12 – 14 ºC. The heating in the turkey housing is locally applied as more ventilation is needed in these systems and this results in higher energy consumption. On a number of farms in the Netherlands recirculation of the air is practised, combining natural and mechanical ventilation. By operating valves, the airflow can be adjusted in such a way that the air is mixed properly and less energy is needed for heating.

Ventilation: Poultry housing can be naturally and/or force-ventilated depending on the climatic conditions and the birds' requirements. The building can be designed to force the ventilation air stream across or longitudinally through the building or from an open ridge in the roof downwards via fans below the cages. For both natural and forced ventilation systems, the prevailing wind direction may influence the positioning of the building so as to enhance the required control of the ventilation airflow as well as to reduce emissions to sensitive areas in the vicinity of the enterprise. Where low outdoor temperatures occur, heating equipment may be installed to maintain the required temperature inside the building.

Ventilation is important for the birds' health and will therefore affect production levels. It is applied when cooling is required and for maintaining the composition of the indoor air at the required levels. For example, for the composition of air in broiler housing, in Belgium the limit values concentrations as shown in Table 2.3 are advised, but these values vary between MSs.

Parameter	Limit value
CO_2	0.20 – 0.30 vol-%
CO	0.01 vol-%
NH_3	25 ppm
H_2S	20 ppm
SO_2	5 ppm

Table 2.3: Advisable limit values for different gaseous substances in the indoor air in broiler housing applied in Belgium
[33, Provincie Antwerpen, 1999]

For layers housed in battery cages, ventilation ranges from 5 – 12 m^3 per bird per hour in summer (depending on the climate zone) and 0.5 – 0.6 m^3 per bird per hour in winter [124, Germany, 2001].

Ventilation systems can be divided into natural and mechanical systems. Natural systems comprise of openings in the ridges of the roof. Minimum outlet sizes are 2.5 cm^2/m^3 of housing volume with a required inlet of 2.5 cm^2/m^3 on each side of the building. With natural systems, the design of the building is important to enhance ventilation. If width and height are not properly matched, ventilation may be insufficient and may give raised levels of odour inside the housing.

Mechanical systems operate with negative pressure and a net inlet of 2 cm^2/m^3 of housing volume. They are more expensive, but give better control of the indoor climate. Different designs are applied, such as:

- roof ventilation
- ridge-parallel ventilation
- side ventilation.

For example in the UK, approximately 40 % of broiler houses may have the ventilation on the roof. Another 50 % have reverse-flow ventilation and 10 % have cross-flow ventilation. Long flow ventilation is an emerging technique, but no further information is made available. In general, broiler-housing facilities are equipped with thermometers at various places to control indoor air temperatures.

For broilers, generally, a maximum ventilation capacity of about 3.6 m^3 per kg live weight is applied in the design of ventilation systems. The air speed at bird level varies with temperature and speed levels of 0.1 to 0.3 m/s have been reported [92, Portugal, 1999]. The ventilation capacity changes with the outside air temperature and relative humidity (RH) and with the age and live weight of the bird (CO_2, water and heat requirements).

The relationship between ventilation needs and the different variables were found to be as follows: with an outside air temperature of 15 °C and a RH of 60 % the ventilation was determined by the CO_2 balance in the first three days, by the water balance in the period up to 28 days and after this by the heat balance. With lower outside air temperatures, CO_2-balance and water balance become more important. From a temperature of 15 °C the heat balance becomes more important in combination with lower RH and heavier chickens. It was concluded that a minimum ventilation requirement for broilers should be set at 1 m^3 per kg live weight, to be on the safe side [33, Provincie Antwerpen, 1999].

Frequency-converter: [177, Netherlands, 2002] In practice, most of the ventilators are powered by a 230-Volt triac controller. One disadvantage of this controller is that a triac-powered ventilator working at low speed leads to energy losses, which leads to a higher energy consumption per cubic metre of air replacement. Another type of controller which can be used to power a ventilator is a frequency-converter, where the ventilators can work at low speed without any decrease in energy efficiency. Up until now the most used system to ventilate a pig house was a system with 1 (or more) fans in each compartment. These fans, provided with a 230 Volt AC motor, are speed adjusted by a simple fan-controller or a climate-computer based on a triac controller.

With the frequency-converter system, as with the conventional system, fans are used in each compartment. Only the fans are different (3*400 Volt AC) and can be adjusted with a frequency controller.

The main benefit of this system over the conventional system is the lower energy consumption. The frequency-converter system can be used in all types of pigs' houses and also in poultry houses. One of the benefits of the system is that all the compartments can be adjusted between

5 % and 100 % ventilation, regardless of the influences of the weather (e.g. even in windy weather). A measuring fan is installed below the fans. The fans in all the compartments are linked with one frequency-converter. The highest demanding compartment controls the power output of the frequency controller of all the fans. The valve, constructed under the fan, of the highest demanding fan is opened to maximum. The other compartments do not need that amount of air, so the other valves close till the measuring fan has reached the RPM calculated by the climate control for that compartment.

This way of smothering is the same as that used with the conventional system with the 230 Volt motor. But, the energy loss through smothering by the frequency-converter system is minimal.

The specific qualifications for controlling the 3*400 Volt motor by the frequency-converter are:

- power-consumption (watt) from a fan controlled by a frequency-converter is reduced to the 3 exponent of the percentage from the normal RPM.
- a great benefit is obtained by adjusting the normal 50 Hz back to a lower frequency. The normal triac-controller reduces the voltage but not the frequency
- very high torque (=power) is delivered to the axle of the fan.

Energy consumption: For example, for a fan with ø 500 mm and 1400 RPM, the power used at the maximum speed is 450 Watts. The power-consumption of a 230 Volt fan at 50 % RPM controlled by the triac-controller uses ± 70 % of 450 Watts, and thus only ± 315 Watts.

The power-consumption of a 3*400 Volt fan at 50 % RPM, controlled by the frequency-converter, is: 0.5 x 0.5 x 0.5 = 12.5 % of 450 Watts = ± 56 Watts. At 80 % and 25 % RPM this is:

- 80 % RPM = 0.8 x 0.8 x 0.8 = 0.512 x 100 % = 51.2 % x 450 Watts = 230 Watts
- 25 % RPM = 0.25 x 0.25 x 0.25 = 0.015 x 100 % = 1.5 % x 450 Watts = 7 Watts

Usually the fans do not work at 100 % RPM. At most times of the year the fans work at a lower RPM. For example, during the winter period the fans seldom work above 25 % RPM. With this RPM the power used is only 7 Watts instead of 112 Watts, using a triac controlled system in combination with a measuring fan. A conventional system without measuring fans cannot even work at that low a level, i.e. of 25 % of the maximum RPM. That means more ventilation of heated air during cold periods and therefore additional energy losses.

The Institute for Applied Research in the Netherlands tested this frequency-converter system for one year. Conclusion: the power reduction achievable by using a frequency-converter system was up to 69 % compared to the 230 Volt motors with the conventional system.

Another benefit of using the frequency-converter is that the fans have a longer lifetime, mainly because there is no extra heat production. Moreover triac controlled systems cause the fans to be jerky, depending upon the revolutions per minute, in contrast to a frequency-converter system, which works more regularly.

Investments costs: The investments costs of the frequency-converter system are quite similar to a conventional system.

2.2.4.2 Illumination

Poultry housing may use only artificial light or may allow natural light to enter (sometimes called ‘daylight’ housing). Laying activity and laying rate can be influenced by the use of artificial lighting.

Illumination is also important for poultry production. Different light schemes are applied with alternating periods of light and darkness. An example is shown in Table 2.4.

Age (days)	Duration (hours light/hours dark)	Intensity at ground level (lux)
1 to 3	24/24	30 – 50
3 and above	24/24 or 24/23 or 1/3	Progressive reduction to 5 – 10

Table 2.4: Example of light requirements for poultry production as practised in Portugal [92, Portugal, 1999]

In turkey housing, illumination is particularly important during the first few days, after which it can be reduced. Light schemes vary from continuous to 14 – 16 hours a day.

2.2.5 Poultry feeding and watering

2.2.5.1 Poultry feed formulation

Feeding is very important, as the quality of feed determines the quality of the product. In particular broiler growth (reaching required weight in only 5 to 8 weeks) depends largely on feed quality. The way feed is obtained varies from purchasing of ready-to-use feed mixtures to the on-farm milling and preparation of the required mixtures, which are often stored in silos adjacent to the birds' housing.

Formulation of poultry feed is very important to meet the requirements of the animals and the production aims and to ensure the right level of energy and essential nutrients, such as amino acids, minerals and vitamins. Feed formulation and the addition of feed substances are regulated on a European level. For each feed substance additive, the relevant directives indicate the maximum dosage, for which species it is applicable, the appropriate age of the animal and whether a withdrawal period has to be observed.

The composition of poultry feed varies considerably – also between MSs –, as it is a mixture of different ingredients, such as:

- cereals and their residuals
- seeds and their residuals
- soya beans and pulses
- bulbs, tubers and roots or root crops
- products of animal origin (e.g. fish meal, meat and bone meal and milk products).

In Spain, for example, pork lard is added to the feed because of the lack of the enzyme lactase, but milk products are not included. And in the UK, 'bulbs, tubers and roots or root crops' are not fed to poultry and neither is bone meal.

The inclusion of the last category of components has now been called into serious question, where there are indications that this practice (feeding processed animal proteins) may have been an important cause of the development of BSE. See also Commission Decision 2000/766/EC. [201, Portugal, 2001]

Elements can be added to poultry feed for different reasons. There are substances that:

1. added in small amounts, can have a positive effect on growth, by increasing the gained weight and improving the feed conversion ratio (FCR). Others (e.g. antibiotics) can have a regulating effect on potential harmful gut flora [201, Portugal, 2001]
2. raise the quality of the feed (e.g. vitamins)
3. have a quality-raising effect on feed, e.g. so called technological additives, such as those that can improve the pressing of feed into granules
4. balance the protein quality of the feed, therefore improving the protein/N conversion (pure amino acids).

Formulating feeds can require the use of linear programming to obtain the required mixtures. All species need sufficient amino acids, but layers in particular require sufficient Ca to produce the eggshell. P is important for its role in the storage of Ca in the bones and will either be fed as a supplement or made more readily available by, for example, feeding phytase. Other minerals and trace elements in the feeds can be more or less controlled as well: Na, K, Cl, I, Fe, Cu, Mn, Se and Zn.

Essential amino acids for poultry are supplied, as their metabolism cannot supply them. They are: arginine, histidine, isoleucine, leucine, lysine, methionine (+cystine), phenylalanine (+tyrosine), threonine, tryptophan and valine. Cystine is not an essential amino acid, but methionine can only be made from cystine and thus they are always linked. As a result of the current ingredients in poultry feed, the most frequent amino acid deficiencies detected in feed mix are sulphur amino acids (methionine and cystine) and lysine. Another quoted deficiency is typically threonine. [171, FEFANA, 2001]

Other elements are not usually added, as they are already sufficiently available in the feed: S and F. Vitamins are not produced by the animals themselves, or are produced in insufficient quantities, and are therefore added to the daily ration. Vitamins are often part of a premix with minerals.

In several MSs the use of antibiotics in feed is under discussion. In several countries feeding without antibiotics is carried out, such as in Sweden, Finland and the UK (only poultry feed), as these have a total ban on the use of all feed antibiotics (including the ones authorised in the EU). See also Section 2.3.3.1 on the use of antibiotics in pig feed.

Apart from the feed formulation, to feed closer to the requirements of the birds, also different types of feeding are given during production cycles. For the different categories, the following number of feeds are most commonly applied:

- layers 2-phase (feeding up to laying, during laying)
- broilers 3-phase (early weeks growing, finishing)
- turkeys 4 - 6 phase (more types for stags than for hens)

Layers can also have a 6-phase feeding, 3 phases up to laying and 3 phases during laying, or 2 to 3 phases up to laying and 1 or 2 phases during laying. [183, NFU/NPA, 2001] [201, Portugal, 2001].

2.2.5.2 Feeding systems

Feeding practices depend on the type of production and bird species. Feed is given in mashed form, crumbs or pellets.

Layers are generally fed ad libitum [183, NFU/NPA, 2001] [173, Spain, 2001]. Meat species, such as broilers and turkeys, are also fed ad libitum. Hand feeding is still applied, but in large enterprises, modern feeding systems are applied that reduce spillage of feed and allow accurate (phase) feeding.

Common feeding systems are:

- chain feed conveyor
- auger conveyor
- feeding pans and
- moving feed hopper.

Chain feed conveyors move feed from storage through the feeding gutter. It is possible to influence the feeding pattern, spilling and rationing by adjusting the velocity of the conveyor. Chain feed conveyors are common in floor systems and are also applied in cage systems.

In the auger conveyor, feed is pushed or pulled through the feeding gutter by a spiral. Spillage is low. Application is common in floor systems and aviary systems.

Feeding pans or bowls are connected with the supply via the transport system. The diameter varies from 300 to 400 mm. Feed is transported by a spiral, chain or a steel rod with small scrapers. The system is designed with a lifting device. They are applied in floor systems (e.g. broilers, turkeys and ducks). In the case of bowls, one bowl feeds approximately 65 – 70 birds. For feeding of turkeys, feeding pans are used in the earlier life-stage, but at a later stage feeding barrels (50 – 60 kg) are also used. Feed is supplied in large buckets or square feeding troughs. Tube feeding systems are increasingly applied to reduce spillage.

A feed hopper is a moving system applied in battery systems. It moves alongside the cages on wheels or a rail and is equipped with a funnel shaped hopper. Moved by hand or electrically, this system fills the feeding trays or gutters.

2.2.5.3 Drinking water supply systems

For all poultry species water has to be available without restriction. Techniques applying restricted watering have been tried, but for welfare reasons this practice is no longer allowed. Various drinking systems are applied. Design and control of the drinking system aims to provide sufficient water at all times and to prevent spillage at the same time and further wetting of the manure. There are basically three systems [26, LNV, 1994]:

- nipple drinkers
    - high capacity nipple drinkers (80 – 90 ml/min)
    - low capacity nipple drinkers (30 – 50 ml/min)
- round drinkers
- water troughs.

Nipple drinkers have various designs. Usually they are made of a combination of plastic and steel. The nipples are placed underneath the water supply pipe. High capacity nipple drinkers have the advantage that the animal quickly receives a proper amount of water, but has the disadvantage of leaking water during drinking. To catch this leakage, little cups are installed underneath the nipples. The low capacity nipple drinkers do not show the problem of leaking water, but it takes more time for an animal to drink enough water. In aviary systems the drinking hen may block the path of the hens on their way to the nest, and subsequently the eggs can end up in the litter instead of in the nest. [206, Netherlands, 2002]

In floor housing, the nipple drinker system can be installed in such a way that it can be lifted out (for example for cleaning, mucking out). It works with low pressure. A pressure control system is installed at the beginning of each pipe, with a water gauge to measure the consumption.

Round drinkers are made of strong plastic and have different designs depending on the type of bird or the system they are applied to. They are usually attached to a winched line and can be pulled up. They work on low pressure and are easily adjustable.

Water troughs are placed on or below the water supply pipe. There are two designs that either automatically have water in the cup or that supply water when a metal strip is touched.

In most layer housing systems automatic watering systems are applied using nipple drinkers. In the Netherlands 90 % of the water supply systems for layers are nipple drinkers and 10 % are round drinkers [206, Netherlands, 2002].

Drinker system for layers	Number of animals per system			
	Cage system	Enriched cage	Floor system	Aviary system
Nipple drinker (birds/nipple)	2 – 6	5 [1)]	4 – 6 [1)]	10
Round drinker (birds/drinker) [2)]	-	-	125	-
Water trough (birds/trough)	-	-	80 – 100	-

1) nipple drinkers with cup design
2) round drinkers are also used in other systems to a much lesser extent

Table 2.5: Applied number of animals per drinker system in different cages [124, Germany, 2001]

However, minimum standards on drinking systems for the protection of laying hens are laid down in Directive 1999/74/EC.

In broiler houses watering points are installed in many places. A commonly used system consists of round drinkers and nipples drinkers. The round drinker design gives every bird easy access to water and aims at minimum spillage to prevent wetting the litter. With cups, 40 animals are served and with drinking nipples 12 – 15 animals per nipple is applied.

In the UK nipple drinkers are more commonly applied to broilers than round drinkers, but in the Netherlands only 10 % of the water supply systems for broilers are nipple drinkers and 90 % are round drinkers. [183, NFU/NPA, 2001] [206, Netherlands, 2002]

Drinking water for turkeys is supplied using round drinkers, bell drinkers or water troughs. Round drinkers and troughs can differ in size according to the stage of production (smaller or larger birds). Nipple drinkers are generally not applied, as turkeys do not use these effectively.

2.3 Pig production

2.3.1 Pig housing and manure collection

The information exchange on the intensive rearing of poultry and pigs confirmed the conclusions of an inventory of European pig housing systems. This inventory, drawn up in 1997, highlighted that there are large differences in pig housing systems between countries as well as within countries [31, EAAP, 1998]. Factors that are considered to be responsible for this variation are:

- climatic conditions
- legislation and socio-economic issues
- economic value of pig sector and profit
- farm structure and ownership
- research
- resources
- traditions.

It is expected that this variation will slowly disappear with increased requirements laid down by directives concerning animal health and welfare, as well as with increased market demands and public concern about the food production chain.

In intensive pig production, different designs apply to different stages of production. The different groups that can be distinguished require different conditions (temperature and management). The following housing systems for sows and pigs can be distinguished:

- housing systems for mating sows
- housing systems for gestating sows
- individual housing systems for lactating sows
- housing systems for weaned piglets (from weaning up to 25 – 30 kg LW)
- housing systems for growers-finishers (from 25 – 30 kg up to 90 – 160 kg of LW).

Intensive pig production applies the all-in/all-out (or batch) system. Also, in order to protect the pigs from infectious diseases, production animals that are brought from outside into a piglet or combined pig production unit may be put in quarantine for a minimum required period (e.g. 30 days, Finland). Manure obtained from this section is usually removed directly to the manure store and not through a manure channel in the pig house. This housing system is not separately addressed in this section.

For all systems, variations in flooring consist of the application of fully-slatted (FS), partly-slatted (PS) or solid (concrete) floors (SCF) and the use of straw or other litter. Slats can be made of concrete, iron or plastic and have different shapes (e.g. triangular). The area of open surface is approximately 20 – 30 % of that of the slatted surface.

In the systems housing sows (without offspring), a distinction is also made between group and individual housing, whereas weaners and growers-finishers are always housed in a group.

Systems for removing manure and urine are related to flooring system, varying from deep pits with a long storage period to shallow pits and manure channels through which the slurry is removed frequently by gravity and valves or by flushing with a liquid.

A further distinction can be made between housing that is naturally ventilated and housing in which the climate is controlled by heating and/or cooling and by forced ventilation with fans.

The housing construction itself shows a variation comparable to that of the flooring systems. Houses can be constructed of durable material and brick-built to withstand cold temperatures, but much lighter material and open constructions are also used. In some Member States artificial heating is commonly applied to all classes of stock including dry sows. From a study comparing the differences between housing systems in the Netherlands and the UK, it is clear that such differences in application do not have to be linked to differences in climatic conditions.

In the following sections technical descriptions are presented of the commonly applied housing systems for sows, weaners and growers-finishers. The environmental performances and other characteristics are described and evaluated in Chapter 4. The overview aims to be representative for the currently applied techniques, but could never be exhaustive given the observed variation in systems and their adapted designs. Information has been used that can be found [10, Netherlands, 1999], [11, Italy, 1999], [31, EAAP, 1998], [59, Italy, 1999], [70, K.U. Laboratorium voor Agrarische Bouwkunde, 1999], [87, Denmark, 2000], [89, Spain, 2000], [120, ADAS, 1999], [121, EC, 2001], [122, Netherlands, 2001], [123, Belgium, 2001], [124, Germany, 2001] and [125, Finland, 2001].

2.3.1.1 Housing systems for mating and gestating sows

Sows are housed in different systems depending on the phase of the reproduction cycle they are in. Mating sows are kept in systems which facilitate easy contact between boar(s) and sows. After mating, the sows are usually moved to a separate part of the housing for their gestating period.

In [31, EAAP, 1998] the following observations were made on the housing of sows. Mating and gestating sows are housed individually or in groups. Each method has its advantages and disadvantages to both the animal and the farmer. The differences between individual and group housing are in:

- animal behaviour
- health
- labour intensity.

Individual housing systems generally score better on health and labour intensity. For example, individually housed sows are limited in their movement, but they are easier to control and there is more tranquillity in the stall, which has a positive affect on the mating and in the early stages of gestation [31, EAAP, 1998]. It is also easier to feed the sows in individual housing, where competition does not a play a role. However, group housing seems to be better for reproduction.

The pattern of application of systems in Europe is similar for both mating and gestating sows:

- mating sows – 74 % individual against 26 % group-housed
- gestating sows – 70 % individual against 30 % group-housed.

In the UK, most **mating** sows (85 %) are group-housed and have access to straw (> 55 %), as a result of British welfare legislation requiring all sows to be loose-housed from weaning to farrowing by 1999. In Member States producing for the UK market (e.g. Denmark) an increasing proportion of group-housing systems can be observed. Denmark has not prohibited individual confinement of sows in mating units, because several Danish studies have indicated that group housing between weaning and 4 weeks post-weaning might increase the risk of embryo loss. As a consequence the number of live-born piglets/litter is reduced compared to individual housing.

In most other countries individual housing, i.e. stalls, is increasingly applied for mating sows.

Group-housing of **gestating** sows is tending to increase overall in those countries which have prohibited the use of stalls and tethers. Tether systems are rapidly decreasing in all countries and no tethering will be allowed from 31 December 2005 onwards [132, EC, 1991]. This system will therefore not be considered in the overview of applied sow housing techniques.

In the UK, the majority (80 %) of gestating sows are also group-housed and have access to straw (60 %) for the reasons mentioned above. In Germany, Ireland and Portugal loose-housing systems for gestating sows are increasing even though these countries have not banned confinement systems for sows, but here market, welfare and costs of production play a role.

In general, sow housing in Spain and France is dominated by stalls and in Spain, France, Greece and Italy these systems are used increasingly. In Italy, in a minority of cases, gestating sows are kept in individual stalls for the total pregnancy period. The majority of sows are kept in stalls for up to 30 days and are then moved to group pens after the pregnancy is confirmed.

The use of straw in the group-housing of sows is still limited, but is expected to increase under the influence of animal welfare considerations and because of indications that fibre might reduce aggression in sows housed in a group.

2.3.1.1.1 Individual housing with a fully or partly-slatted floor for mating and gestating sows

This way of housing mating and gestating sows is very common. The crates measure about 2 m x 0.60 – 0.65 m and the rear end is equipped with concrete slats over a deep pit in which slurry and cleaning waters are stored. Feeding systems and drinkers are placed at the front end.

A central slatted alley runs between the rows of crates and a concrete-floored gangway runs on either side of the crates for feeding. In the mating house, there will be pens for housing the boars (Figure 2.13). These pens are absent in the housing section for gestating sows.

Slurry is collected under the slats and stored in a deep or a shallow pit. The slurry removal rate depends on the pit size. Natural or mechanical ventilation is applied and sometimes a heating system.

The picture shows a common design, but various other designs (with partly-slatted floors (PSF)) are applied to enhance intensive contact between boar and sows. Also, the sows may face the central alley with the troughs placed on the inner side and the slatted area will be at the side corridors.

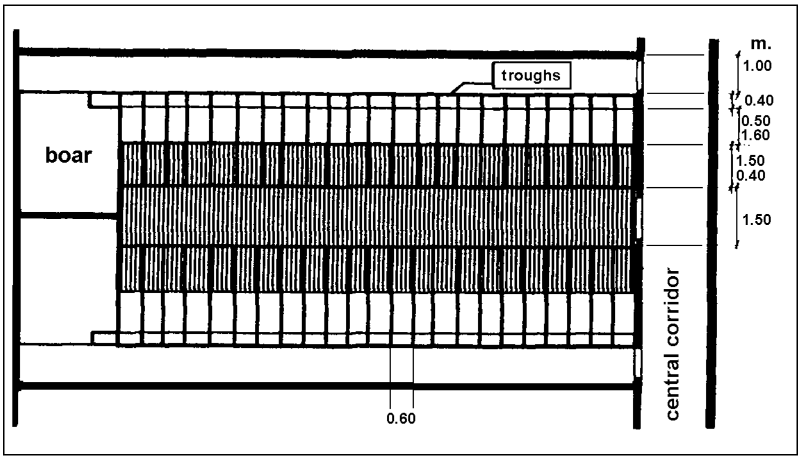

Figure 2.13: Schematic overview of a housing design for mating sows on a partly-slatted floor [31, EAAP, 1998]

2.3.1.1.2 Sow crates with a solid floor for mating and gestating sows

In this system mating and gestating sows are housed on concrete floors in a similar way to the design with the PSF, but there is a difference in the design applied to the floor and the removal of manure. Again, feeding and watering are applied at the front of the crate. In the central alley there is a drain-system for removal of urine. Mucking-out of manure and straw (where that is applied) is done frequently.

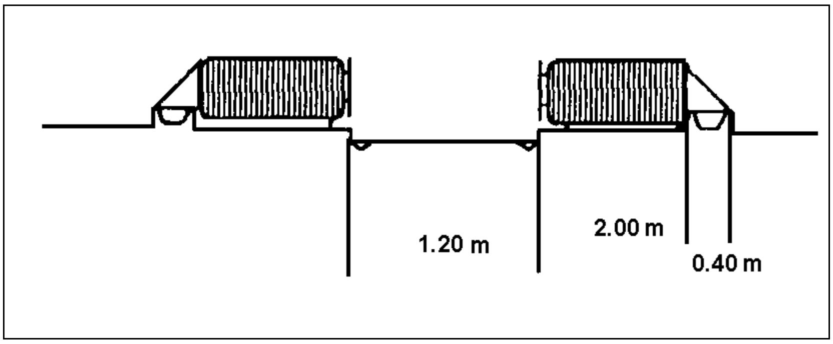

Figure 2.14: Floor design for sow crates with a solid concrete floor for mating and gestating sows [31, EAAP, 1998]

In these systems ventilation is natural when straw is applied and mechanical in insulated buildings where no straw is used.

2.3.1.1.3 Group housing with or without straw for gestating sows

Two basic designs for group housing of mating and gestating sows are applied. One system has a solid concrete floor with deep litter and the other design has slatted floors at the dunging area and the feeding stalls. The solid part is (almost) completely bedded by a layer of straw or other ligno-cellulosic materials to absorb urine and incorporate faeces. Solid manure is obtained and has to be frequently removed in order to avoid the litter becoming too moist. A frequency of removal of 1 – 4 times a year has been reported but this depends on the litter type, the depth of the bedded area and on general farm management. The frequency of complete litter removal can be higher in Italy, e.g. up to 6 – 8 times. In addition, partial removal of the moistened litter can be carried out weekly. In the case of one cleaning per year, it is spread directly onto the field. With more cleanings the litter is generally stored, such as in a field clamp.

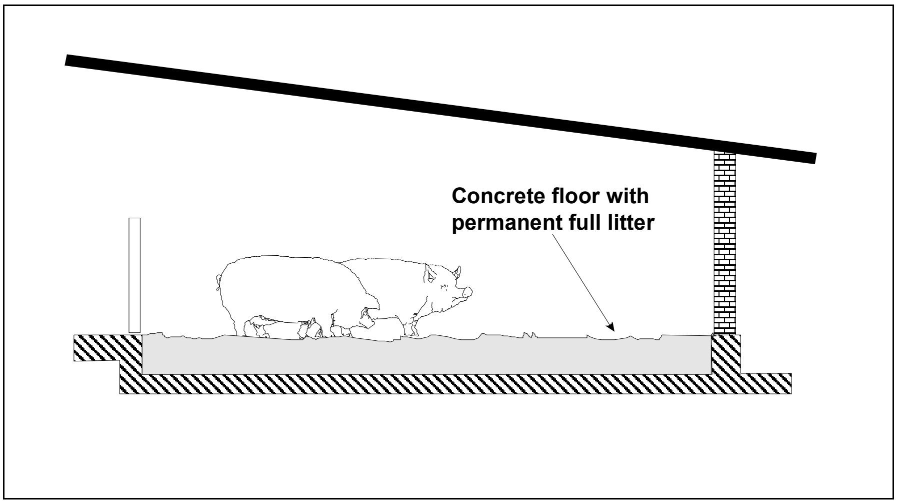

Figure 2.15: Example of group-housing for gestating sows on a solid concrete floor with full litter [185, Italy, 2001]

For the ventilation of this housing the same principle applies as for the individual housing of sows. With the application of straw, heating is generally not applied as, at low temperatures, the sows are able to compensate by hiding in the deep litter. The design of this system can vary and can contain various functional areas. An example is shown in Figure 2.16.

Manure handling with this system has been described as follows. In units where bedding is used exclusively for rooting, the amount of litter will be so limited that all the manure is handled in the form of slurry. In units with slatted floor in the dunging area, the manure is cleaned daily using underslat scrapers. In units with solid floor the manure is cleaned either daily with scrapers or 2 – 3 times a week using a tractor-mounted tyre scraper. In units with deep litter in the lying area, the litter is removed 1 – 2 times annually.

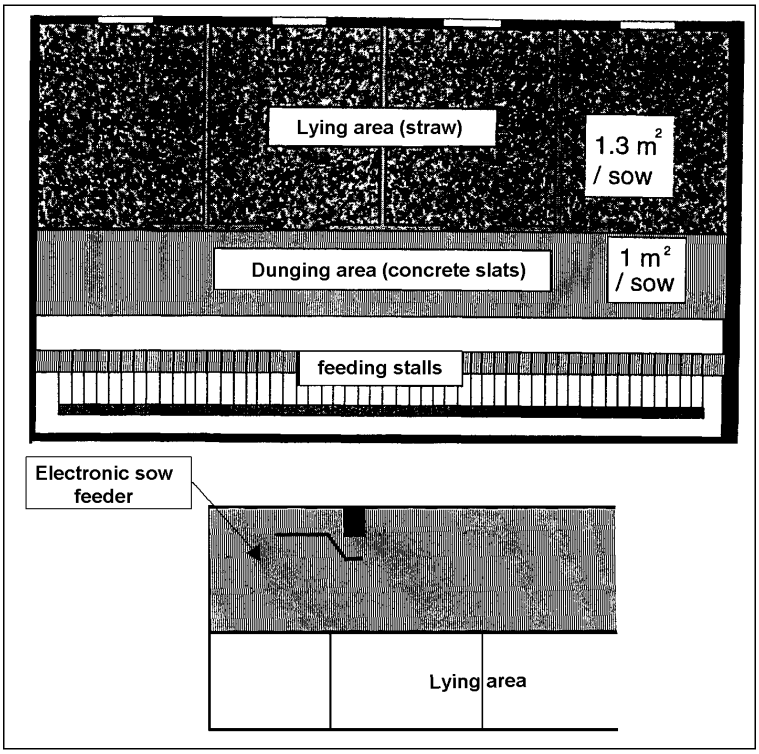

Figure 2.16: Example of a housing system with several functional areas for gestating sows [87, Denmark, 2000]

2.3.1.2 Housing systems for farrowing sows

Shortly before farrowing (about 1 week), gestating sows are moved to farrowing pens. There are different designs of farrowing pens. A common design has partly- or fully-slatted floors and generally no straw. The sows are often confined in their movement, but loose housing is also applied. For example, straw-based and loose housing can be found in the UK. Fully-slatted is applied widely as it is considered to be more hygienic and labour efficient than partly-slatted or solid floors. On the other hand, Danish information indicates that partly-slatted systems are more energy efficient and a gradual increase in partly-slatted systems is being observed. In Austria, the fully-slatted floor systems are in decline [194, Austria, 2001].

General features of farrowing compartments are:

- applied minimum room temperature of 18 °C
- temperature for the sows 16 – 18 °C
- temperature for the piglets about 33 °C
- low airflow, in particular in the piglet area.

2.3.1.2.1 Housing for farrowing sows with confined movement

A cross-section of a typical pen system for farrowing sows is shown in Figure 2.18. Farrowing pen sections generally contain not more than 10 – 12 sows (pens). Pen sizes measure 4 to 5 m^2.

Piglets are housed in these systems until weaning after which they are sold or reared in rearing pens (weaner housing). The floor can be fully or partly slatted. Slats made of plastic or plastic-coated metal are increasingly used instead of concrete, as they are considered to be more comfortable.

The slurry is stored under the slatted floor of the crates either in a shallow pit (0.8 m.), in which case it is removed frequently via a central system in the building, or in a deep pit, from where it is removed only at the end of the lactating period or less frequently.

There is a specific area for the piglets, usually positioned in the central alley (for easier observation) between the pens. This area is generally not slatted and is heated during the first days after birth by using a lamp or by warming the floor or both. The sow is limited in her movement to prevent her from crushing the piglets.

Figure 2.17: Farrowing pen design with a fully-slatted floor (the Netherlands)

Forced or natural ventilation is applied in such a way that the airflow will not disturb the climate at floor level (around sow and pigs). In modern closed housing, fully automatic climate control is applied, thereby maintaining the temperature and humidity in the farrowing section at a constant level.

The position of the sow is often as pictured in Figure 2.18, but the crates are also put the other way around with the sows facing the alley. In practice, some farmers have observed that this position makes the sows more relaxed, as they can more easily notice movements in the alley, whereas in the other position they cannot turn, which makes them more restless.

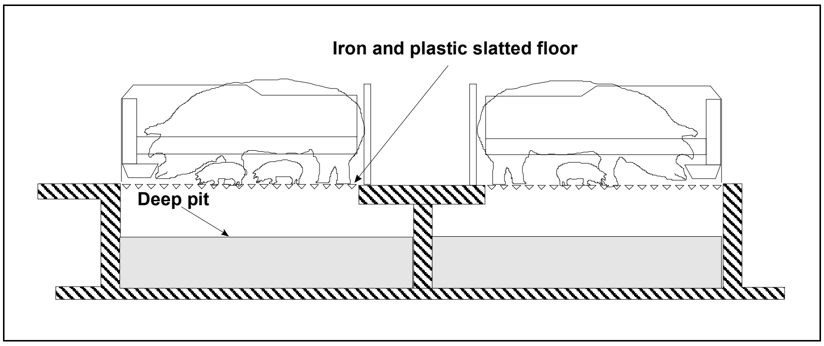

Figure 2.18: Example of confined housing of farrowing sows on a fully-slatted floor with a storage pit underneath
[185, Italy, 2001]

2.3.1.2.2 Housing of farrowing sows allowing sow movement

Farrowing sows are housed without being confined in their movement in systems with partly-slatted floors. A separate lying area for the piglets prevents them from being crushed by the sow. This pen is sometimes used to raise the piglets from weaning until about 25 – 30 kg LW. This design requires more space than the design with restricted sow movement and needs more frequent cleaning. Number of pens or sows per compartment is generally less than 10.

Material for the floor system and heating and ventilation requirements for sow and piglets are the same for this system. With free sow housing, the walls of the pen are slightly higher than for the pen with restricted movement.

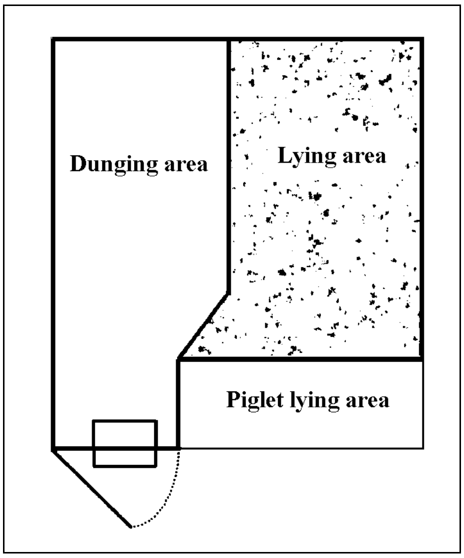

Figure 2.19: Example of an applied plan for a farrowing pen (partly-slatted floor) without restricted sow movement
[31, EAAP, 1998]

2.3.1.3 Housing systems for weaners

Pigs are weaned at approximately 4 weeks (range 3 to 6 weeks), after which they are kept in small groups of the same litter (8 – 12 pigs per pen) up to 30 kg LW (range 25 – 35). However, in the UK the pigs are kept in larger groups. The majority of animals are housed in pens or cages with fully-slatted flooring. Earlier, farrowing pens were frequently used for weaned pigs, but this housing method is apparently being used less and less, except in Greece. The piglets would remain in the pen (see Figure 2.17) after the sow had been taken to another unit and the crate had been removed. The use of pens specifically designed for the rearing of weaned pigs is, however, more common and is increasing, because it offers better environmental control and management than the older systems.

The tendency is that systems with partly-slatted flooring are decreasing in popularity while fully-slatted flooring systems are increasingly becoming popular, except in Denmark, Belgium and the Netherlands. In Denmark systems with a covered lying area and two-thirds solid floor have become increasingly popular in recent years. Research indicates that this system is more energy efficient than commonly used heated nurseries. Moreover, pen fouling is not a problem, which is one of the main reasons why pig producers tend to select fully-slatted flooring over partly-slatted flooring. In Belgium and the Netherlands there are strong incentives to reduce ammonia emissions and research has indicated that increasing the amount of solid floor (or reducing the slatted) might reduce emissions. Farmers are therefore rewarded for installing such systems [31, EAAP, 1998].

A large proportion (40 %) of the weaners in the UK are housed in relatively cheap straw-based systems, which may be explained by the mild climatic conditions and a tradition of using low-cost housing systems. Straw-based systems are also popular in Denmark and France. In both countries large amounts of straw are available and pig production is normally tied in with crop production (cereals) following a long tradition of using straw from crops in animal production.

Housing of weaners on fully- or partly-slatted floors is very similar to the housing of growers/finishers (Figure 2.20).

The housing is equipped with mechanical ventilation, either negative pressure or balanced pressures type. Ventilation is dimensioned at an output of maximum 40 m^3/h per place. Auxiliary heating is used in the form of electric fan heaters or a central heating plant with heating pipes.

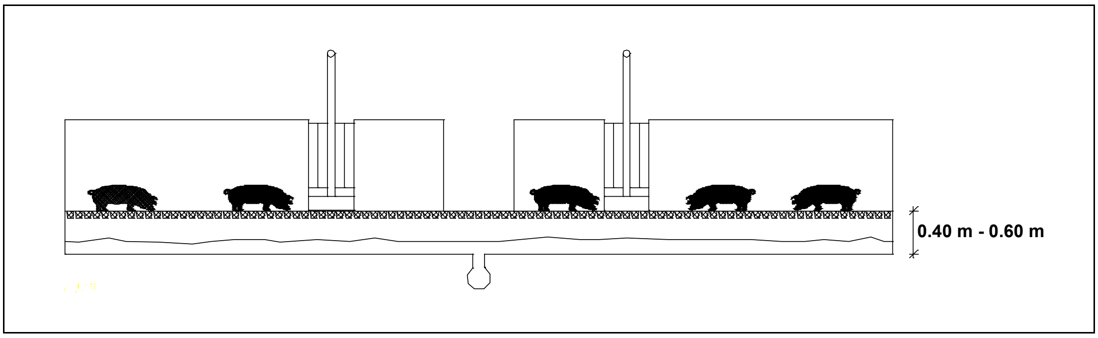

Figure 2.20: Cross-section of rearing unit with fully-slatted floor and plastic or metal slats [87, Denmark, 2000]

Manure is handled in the form of slurry and is drained mainly through a pipe discharge plant where the individual sections of the manure channels are emptied via plugs in the pipes. The channels can also be drained via gates. The channels are cleaned after the removal of each group of pigs, often in connection with the cleaning of the pens, i.e. at intervals of 6 – 8 weeks.

In the partly-slatted design a covered lying area is applied which can be removed or lifted, once the pigs have grown and need more ventilation.

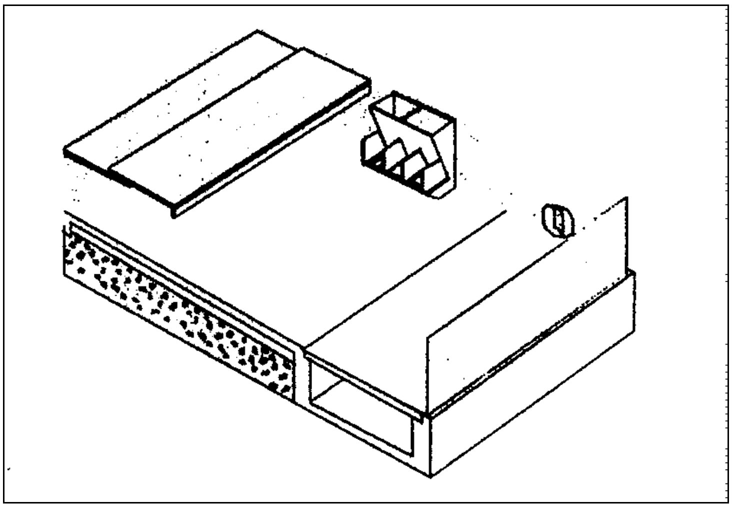

Figure 2.21: Schematic picture of a weaner pen with a partly-slatted floor (1/3) and a cover above the lying area
[31, EAAP, 1998]

A special design is the housing of weaners in flat decks [133, Peirson/Brade, 2001]. Flat decks were initially developed in the late 1960s and early 1970s as a specialised housing system to provide controlled environment housing for piglets, weaned at 3 to 4 weeks of age, through to 15 – 20 kg live weight. The concept has been extended and is also used to provide second stage housing from about 15 – 20 kg through to weights of up to 50 or 60 kg when pigs make their final move into finishing pens. The thermally insulated buildings used are often of a pre-fabricated sandwich construction with external wood or panel cladding, thermal insulation and panelled internal cladding. The internal layouts and structures have also been installed inside more permanent buildings.

Flat decks are built around a batch system so that each room is stocked on an “all in – all out” basis with piglets from a batch of sows farrowed in the same week. Early designs were based on small group sizes – around 10 pigs per pen – but pen group sizes have tended to increase in recent years.

The original concept was based on fully-slatted pen floors suspended over slurry channels (or tanks) and pens down one or both sides of a feed/access passage. Fully-slatted flooring was seen as an important hygiene/health feature because it separates piglets from their faeces and urine. Floors were originally “weldmesh” or expanded metal. More recently plastic flooring has been used. The pen floor level was originally raised (in comparison to that of the passage floor), but more recent designs have passages and pen floors at the same level.

Ventilation is almost exclusively provided by extractor fans. Typically, air is drawn into each room through inlets in one end of the room from an access passageway common to a group of flat deck rooms. Inlet air is preheated, as necessary, by automatically controlled heaters. Extractor fans, normally situated in the opposite wall, are intended to create air movements across the room, and radiant heaters above the pens (or underfloor heating) provide additional temperature/comfort control.

Feed is normally provided as dry pellets or meal offered in ad-lib hoppers on the front (passage) side of each pen. Slurry is removed from the below-slat channels or tanks at the end of each stocking batch. Pens are power-washed between batches.

Room temperatures are maintained at 28 – 30 ºC for the first few days after weaning and are then reduced as the piglets grow. Occupation is usually 4 – 5 weeks in the first-stage pens, and by the end of this period temperatures would have been reduced to 20 – 22 ºC.

Many features of flat decks have evolved and been developed over the years. Now the term flat deck is often used to loosely describe almost all slurry-based weaner-housing systems, many of which bear little resemblance to the original concept. Some farmers have provided solid floored lying areas to help improve pig comfort and welfare. Underfloor heating has become a more common feature. Group sizes have tended to increase and the system is slowly evolving into a "nursery" room system with groups of up to around 100 pigs in a group in a partially solid-floored pen (around one third of the floor area solid) and no access passageways.

2.3.1.4 Housing of growers-finishers

From an average LW of 30 kg (25 – 35 kg) pigs are moved to separate sections to be grown and finished for slaughter. It is not uncommon to house growers (e.g. up to 60 kg) and finishers (from 60 kg onwards) in separate sections, but the housing facilities are very much the same. The housing systems used for growers-finishers can be compared with weaner houses (Section 2.3.1.3), except that most grower/finishers are kept in systems with little or no straw. Partly- and fully-slatted flooring are equally common, but there is a trend towards more fully-slatted flooring except in Belgium, Denmark, the Netherlands, and the UK.

The growing-finishing housing is a brick-built, open or closed, insulated construction for 100 to 200 pigs. It is usually divided into compartments for 10 – 15 pigs (small groups) or up to 24 pigs (large groups). The pens are arranged either with the aisle on one side or in a double row with the aisle in the centre. In the pens with a solid concrete floor, movable covers are used to cover the lying area, at least during the first stage of the growing period.

Feed distribution is usually automated and can be sensor-controlled. Liquid or dry feeding is applied ad-lib or restricted and multi-phase (adapted N and P content). Design of feeding troughs and drinkers depends on type of feeding.

2.3.1.4.1 Housing of growers-finishers on a fully-slatted floor

This housing system is very common for small (10 – 15 pigs) and large groups (up to 24) of growers-finishers. It is applied in closed, thermally insulated housing with mechanical ventilation and in houses with natural ventilation. Windows allow daylight in and electrical light is used. Auxiliary heating is applied only when necessary, as the pigs' body-heat is usually capable of satisfying the heat requirement.

The pen is fully slatted and has no physical separation of the lying, eating and dunging areas. The slats are made of concrete or (plastic coated) iron. Manure is trodden through and urine mixes with the manure or runs off through urine/liquid manure channels. The slurry is collected in a manure pit under the fully-slatted floor. Depending on the depth of the pit, it may provide for an extended storage period (high ammonia levels in the house) or it is emptied frequently and the slurry is stored in a separate storage facility. A frequently applied system has the individual sections connected by a central drain, into which they are emptied by lifting a plug or a gate in the pipe.

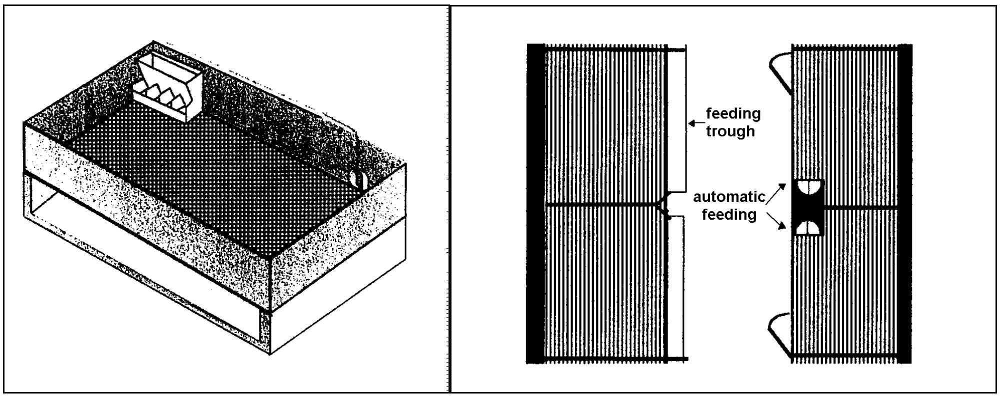

Figure 2.22: Example of a single growing-finishing pen with a fully-slatted floor and examples of two pen layout with different feeding systems
[31, EAAP, 1998]

2.3.1.4.2 Housing of growers/finishers on a partly-slatted floor

Partly-slatted floor systems are applied in similar buildings to those used for fully-slatted-floor systems. The floor is divided into a slatted and a solid/non-slatted section. There are basically two options: to have the solid concrete floor on one side or in the centre of the pen. The solid part can be flat, convex or slightly inclined (see description below).

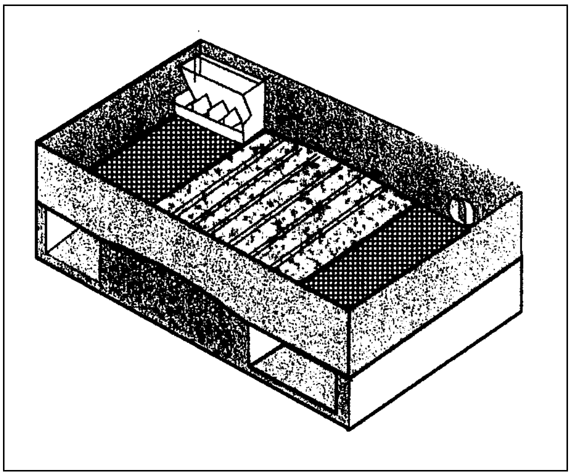

Figure 2.23: Pen design for growers-finishers with partly-slatted (convex) floor and solid area in the centre
[31, EAAP, 1998]

The solid part usually functions as a feeding and resting place and the slatted part is used for dunging. The slats are made of concrete or (plastic coated) iron. Manure is trodden through and urine mixes with the manure or runs off through urine/liquid manure channels. The slurry is collected in a manure pit under the fully-slatted floor. Depending on the depth of the pit, it may provide for an extended storage period (high ammonia levels in the house) or it is emptied frequently and the slurry is stored in a separate storage facility. A frequently applied system has the individual sections connected by a central drain, into which they are emptied by lifting a plug or a gate in the pipe.

Restricted straw is applied in the partly-slatted pen that is designed with a concrete floor and one slatted area (solid/slatted: 2:1). Straw is given in straw racks that are filled manually, and from which the pigs bring the straw in themselves. The solid floor has a slight incline and slurry and straw are moved towards the slats by the pigs' activity and therefore this system is also called straw-flow system. Manure is removed several times a day.

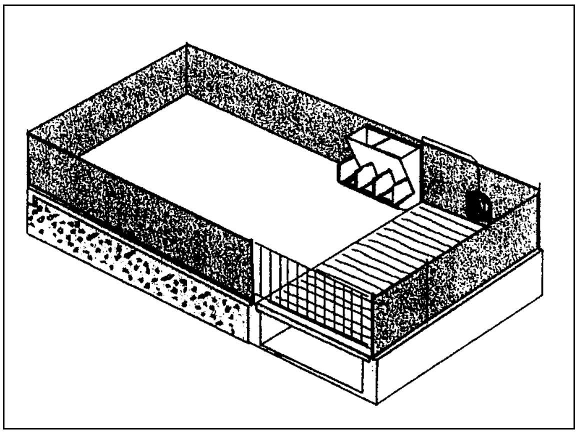

Figure 2.24: Design of a partly-slatted floor system with restricted straw use for growers-finishers [31, EAAP, 1998]

A partly-slatted design is applied in Italy with a solid concrete floor and an external slatted alley adjacent to a manure channel. In each pen, the pigs have their housing and feeding area inside the building, but an opening with a shutter allows them to reach the external dunging area with the slatted floor. The pig activity moves the manure through the slats into the manure channel, which is emptied once or twice a day with a scraper. The manure channel runs parallel to the pig building and is connected with a slurry storage facility. This system is also used for mating and gestating sows in group housing.

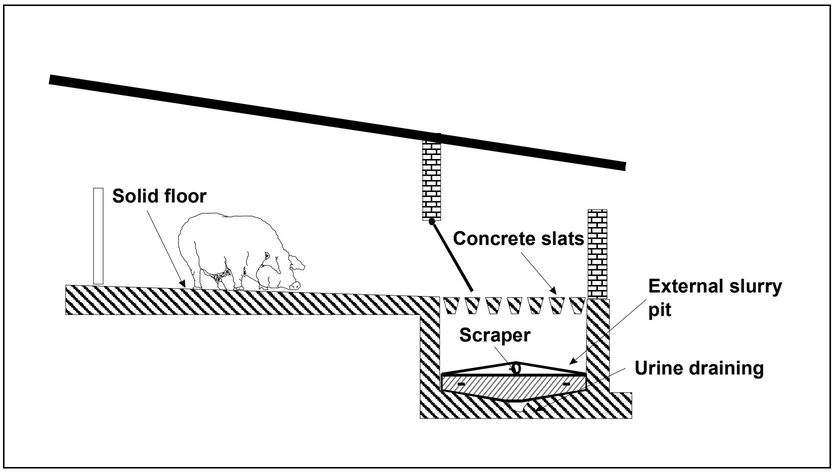

Figure 2.25: Solid concrete floor with slatted external alley and scraper underneath [59, Italy, 1999]

2.3.1.4.3 Housing of growers-finishers on a solid concrete floor and straw

In the housing systems for growers-finishers with a concrete floor, straw is applied in restricted amounts for reasons of animal welfare or by big-bale supply to serve as bedding. These systems are applied in closed buildings or in open-front houses. The open-front designs are equipped with wind barriers (netting or spaceboards), but also straw bales are used for insulation and protection against the wind.

Figure 2.26: Open front design using straw bales for protection (UK)

Pen designs can vary, but usually there is a lying area with straw and a feeding area, which may be elevated and accessible by steps. The lying area may be covered. The pens may be positioned on one side of the building or on either side of a central aisle. Dunging takes place in the littered area. Mucking-out and cleaning are usually done with a front-end loader after each batch. Group size may be 35 – 40.

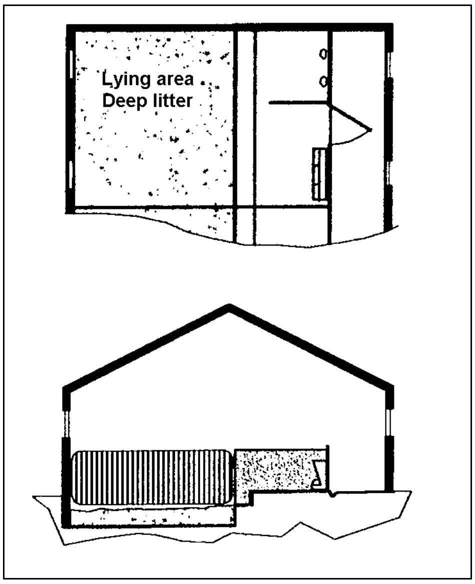

Figure 2.27: An example of a solid concrete floor system for growers-finishers [31, EAAP, 1998]

As with the partly-slatted design, a solid concrete floor system is applied in Italy with a littered external alley. The pen area inside is used for lying and feeding and has very little or no straw. The outside dunging area is littered and connected with a manure channel. Manure and straw are moved into the channel by the pigs' activity. Manure is removed once or twice daily by a drag chain or a scraper to an outside manure storage.

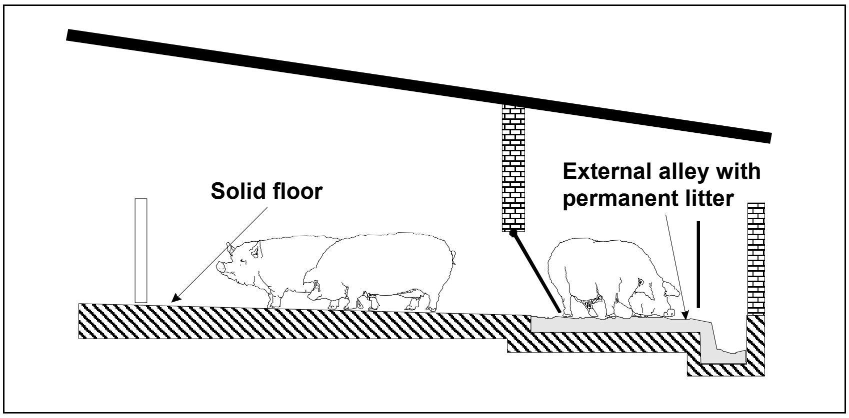

Figure 2.28: Solid concrete floor with external littered alley and manure channel [59, Italy, 1999]

2.3.2 Control of pig housing climate

The indoor climate in pig housing systems is important, as ammonia, combined with dust, is known to be a frequent cause of pig respiratory diseases, including atrophic rhinitis and enzootic pneumonia. Since stock workers can also be subject to respiratory health issues [98, FORUM, 1999], it is doubly important that pig housing be sufficiently ventilated.

Minimum (qualitative) requirements are laid down in Directive 91/630/EEC [132, EC, 1991] for the control of the pig housing climate. Temperature and humidity of air, dust levels, air circulation and gas concentrations must be below harmful levels. For example, the limit value concentrations shown in (Table 2.6) are advised, but these values vary between MSs. A good atmosphere in the house can be achieved by:

- insulation of the buildings
- heating
- ventilation.

Indoor environment factors	Level/occurrence
CO	Below measurable value
H_2S	Below measurable value
Relative humidity H	Pigs up to 25 kg : 60 – 80 % Pigs 25 kg upwards : 50 – 60 %
NH_3	Maximum 10 ppm
Air velocity	Farrowing pens and weaners: <0.15 m/s Mating and gestating sows: <0.20 m/s
CO_2	Max. 0.20 volume-%

Table 2.6: General indicative levels of indoor environment for pigs [27, IKC Veehouderij, 1993]

Performance of the applied systems is affected by:

- design and construction of the building
- position of the building in relation to wind directions and surrounding objects
- application of control systems
- age and production stage of the pigs in the housing.

2.3.2.1 Heating of pig housing

The need for temperature control in pig housing depends on climatic conditions, construction of the building and stage of production of the animals. In general, in colder climates or climates with periods of low temperatures, buildings are insulated and equipped with mechanical ventilation. In warmer regions (Mediterranean latitudes), high temperatures are a greater influence on welfare and productivity of adult pigs than low temperatures. Usually there is no need to install heating systems; animal body heat is generally sufficient to maintain welfare temperature within installations. In this context, climate control systems are mainly designed to guarantee good air circulation.

In some housing systems for sows and growers-finishers, large amounts of straw help the animals to maintain a comfortable temperature. However, the most important factors are live weight, age and production stage. Other factors that affect temperature requirements are:

- individual or group housing
- flooring system (fully- or partly slatted or solid floors)
- amount of feed (energy) the animals get.

<table>
<tr><th>Farrowing pen</th><th colspan="2">Weaned pigs</th><th colspan="2">Mating and gestating sows</th><th colspan="2">Growers-finishers</th></tr>
<tr><td rowspan="2">Room, 1st week
up to 20 °C</td><td>7 kg</td><td>up to 25 °C</td><td>Mating</td><td>up to 20 °C</td><td>20 kg</td><td>up to 20 °C</td></tr>
<tr><td>10 kg</td><td>up to 24 °C</td><td>Early gestation</td><td>up to 20 °C</td><td>30 kg</td><td>up to 18 °C</td></tr>
<tr><td rowspan="3">Piglet area, 1st days
up to 30 °C</td><td>15 kg</td><td>up to 22 °C</td><td>Middle gestation</td><td>up to 18 °C</td><td>40 kg</td><td>up to 16 °C</td></tr>
<tr><td>20 kg</td><td>up to 20 °C</td><td>End of gestation</td><td>up to 16 °C</td><td>50 kg</td><td>up to 15 °C</td></tr>
<tr><td>25 kg</td><td>up to 18 °C</td><td colspan="2"></td><td colspan="2"></td></tr>
</table>

Table 2.7: Example of applied temperature requirements for calculation of heating capacity in heated housing for different pig categories in healthy condition
[27, IKC Veehouderij, 1993]

Pig housing can be heated by various systems. Heating is applied as local heating or room heating. Local heating has the advantage that it is aimed at the place where it is most needed. Systems applied are:

- floors equipped with heating elements
- heating elements above the pig places radiating heat onto the animals as well as onto the floor surface.

Room ventilation is applied by two methods:

- by preheating: incoming air is preheated by leading the air through a central corridor to warm it to a minimum temperature, to reduce temperature fluctuations and to improve air movement in the housing area
- by post-heating: heating is applied to the air once it has entered the housing area, to reduce temperature fluctuations and to reduce heating cost.

Heating can be direct or indirect. Direct heating is accomplished by applying installations such as:

- gas heat radiators: infra-red, gas air heaters and gas-fuelled radiation convectors
- electric heat radiators: special light-bulbs or ceramic radiators
- electric floor heating: on matting or in the floor
- heaters/blowers.

Indirect heating can be compared to central heating in domestic applications. The installations applied can be:

- standard boilers (efficiency: 50 – 65 %)
- improved efficiency boilers (improved efficiency: 75 %)
- high efficiency boilers (high efficiency: 90 %).

Boilers can be open or closed design. Open designs use indoor air for the burning process. Closed designs draw air from outside the building and are particularly suitable for dusty areas.

2.3.2.2 Ventilation of pig housing

Ventilation systems vary from manually controlled natural systems to fully automated fan-based systems. The following basic systems are examples of commonly used ventilation systems:

- Mechanical systems:
  - exhaust ventilation
  - pressure ventilation
  - neutral ventilation.
- Natural systems
  - hand controlled ventilation
  - automatically controlled natural ventilation (ACNV).

With mechanical systems, the distribution of air can be accurately adjusted by means of valves, positioning of the fan(s) and diameter of the air inlets. Natural ventilation depends more on the natural fluctuations of the outside air temperature and on the wind. With fans, more even airflow in the housing can be achieved. This is important when considering the application with housing systems, as the interaction between the housing (flooring) system and the ventilation system affects the air currents and temperature gradients in the house. For example, partly-slatted floors may combine better with mechanical ventilation than with natural ventilation, whereas with fully-slatted floors, natural ventilation may be equally applied [120, ADAS, 1999].

The volume of the housing area and the openings of air inlet and outlet have to correspond to create the required ventilation rate at all times. Irrespective of the production stage and the ventilation system, a draught stream close to the animals must be avoided. Until recently, the majority of ventilation and heat supply systems were installed independently, but in new installations (e.g. in Denmark) it is common to apply integrated installations that match heating and ventilation requirements [87, Denmark, 2000].

Control and adjustment of ventilation are important and can be carried out in different ways. Electronic equipment is applied to measure the revolutions per minute. A measuring fan in a ventilation tube can be used to measure the air velocity in the tube, which is related to a certain pressure and revolution rate.

The following principal ventilation techniques can be applied in pig housing [27, IKC Veehouderij, 1993] [125, Finland, 2001].

Exhaust ventilation in pig housing is ventilation by running fans in the sidewalls or in the roof. Adjustable ventilation openings or windows allow fresh air to be drawn in. Fans exhaust air outside, usually through the ceiling at one or more points. This creates under-pressure, and creates fresh airflows into the building through inlets. Fresh air inlets are usually on the wall close to the ceiling or in the ceiling, so that the air flows from between the roof and the ceiling to the outlet. It is typical in an exhaust ventilation system for the air pressure inside the building to be lower than outside. Exhaust ventilation works well when it is warm outside and it is therefore a very popular and appropriate system in countries with warmer climates. On growing-finishing pig farms, heating costs may be relatively low when exhaust ventilation is used, provided that it is properly adjusted.

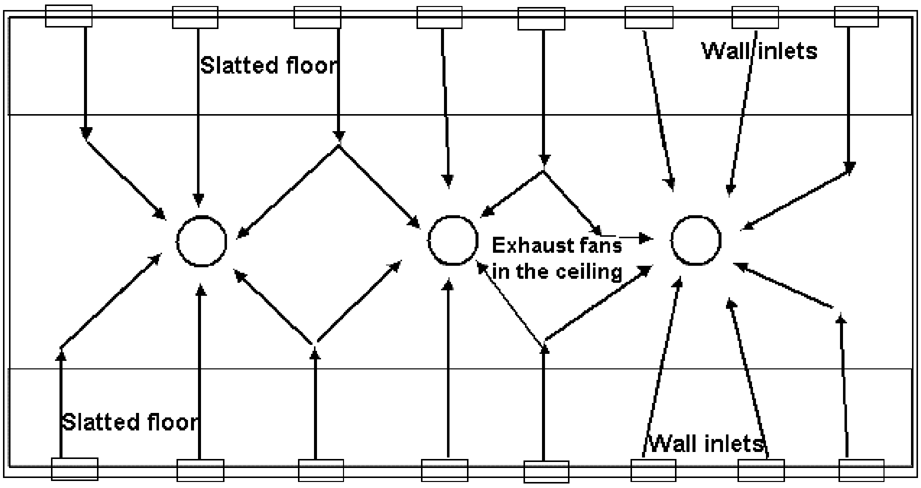

Figure 2.29: Schematic picture of airflow in an exhaust ventilation system
[125, Finland, 2001]

In buildings with a pressure ventilation system, fans are used to blow air into the building, which means that the air pressure inside the building is higher than outside. Due to the difference in the pressure, air flows out of the building through outlets. When using pressure ventilation the air entering the building can be preheated, and thus part of the heating in the winter can be done by means of ventilation. The main problem in this system is that the airflow is quite uneven when only one blowing point is used. Airflow is rapid and the air is cold close to the fan, but the airflow slows down rapidly when moving further away from the fan. Blowing channels may be used to avoid this problem. Blowing channels are usually placed in the middle of the pig house.

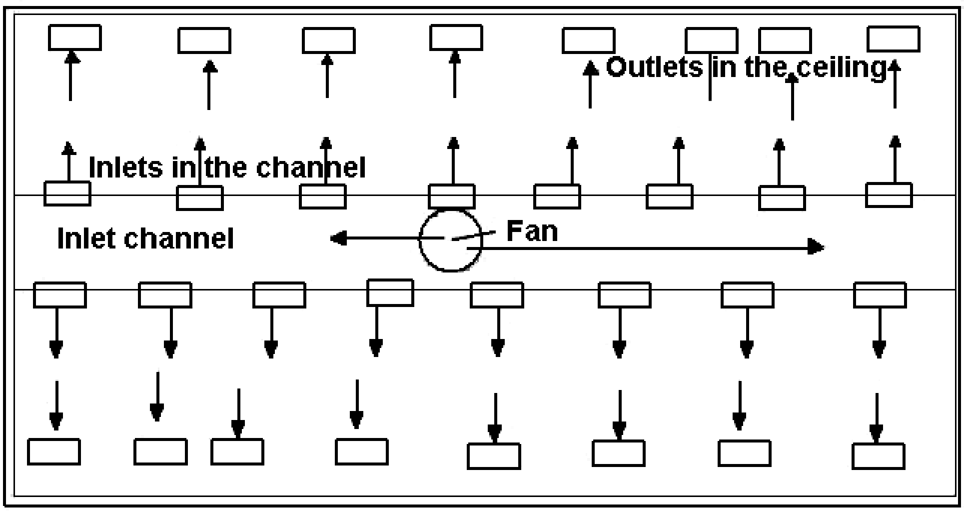

Figure 2.30: Schematic picture of airflow in a pressure ventilation system
[125, Finland, 2001]

Air is blown into a channel, which spreads it through the building. The airflow, distribution and direction of the blow are controlled by means of nozzles. Sometimes humidity is a problem, which due to the higher pressure inside than outside leads to condensation on the surfaces of the channels when the air is not preheated. This is why pressure ventilation is not very common in colder climates. It can only be used in concrete buildings because the humidity can damage insulating materials and structural timbers.

A neutral ventilation system is a combination of the exhaust and pressure ventilation systems. As with exhaust ventilation, the exhaust air is drawn out of the building by means of a fan. However, the replacement air does not flow into the building because of negative pressure in the building, but air is drawn in through a channel. Thus, the difference between the air pressure inside and outside the building is much smaller than in the case of exhaust or pressure ventilation. In neutral ventilation, a heat exchanger can be used to reduce the need for additional heating. Neutral ventilation uses more energy than exhaust or pressure ventilation, because the air is drawn in and blown out. Investment costs are also higher, because twice as many blowers and blowing channels are needed as for the other systems.

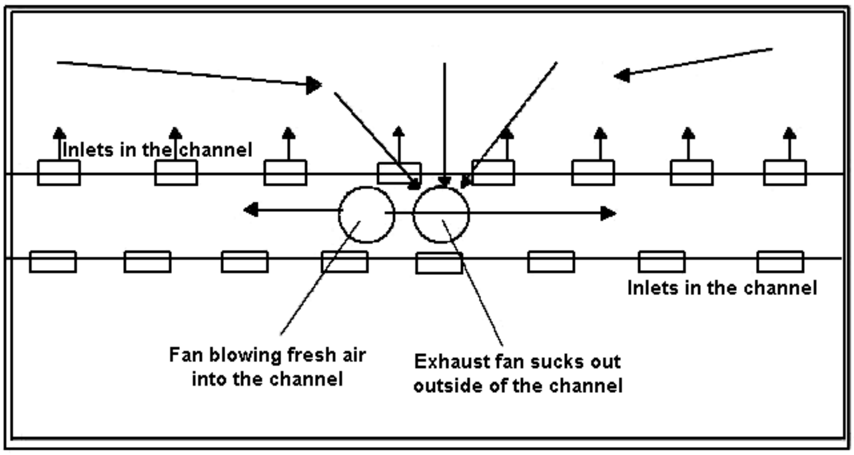

Figure 2.31: Schematic picture of airflow in a neutral ventilation system [125, Finland, 2001]

Natural ventilation systems are based on the difference in density and air pressure between warm air and cold air due to wind, temperature and the so-called “chimney effect” that cause warm air to rise and cold air to replace it. The “chimney effect” depends on the relation between opening and position of air inlets and outlets and the inclination of the roof (25º; 0.46 m per metre stall width). Obviously, design and construction of the building are very important with natural ventilation. As the effect is based on temperature differences, it is clear that the effect is largest when the ventilation requirement is at its lowest (in winter).

The naturally created negative pressure is relatively small, even in winter in Finland reportedly less than 20 Pa, and in summer may have to be assisted by exhaust pressure ventilation. Thus, combinations of ventilation systems are applied that work alternately depending on the indoor and outdoor air temperatures. In countries such as the Netherlands wind is the prevailing factor that influences natural ventilation.

Automatically adjustable valves in the air inlets can be applied to control natural ventilation (ACNV). Sensors at pig level send a signal to the system that adjusts the opening of the inlets and thus increases or reduces the airflow.

Ventilation by drawing air from the manure pit in slatted floor systems is also applied and is considered an efficient way to reduce concentrations of manure gases in the house. This system has specific requirements of length and diameters of the air channels.

Irrespective of design or principle applied, ventilation systems have to provide the required ventilation rate, which varies with the different production stages and the time of year. Air velocity around the animals must be kept below 0.15 – 0.20 m/s to avoid a sense of draught.

Mating and gestating sows have relatively low temperature requirements. In Spain and Italy, many farms apply only natural ventilation, with air entering from outside directly into the animal housing area. Nevertheless, in large installations, with a high density of animals, ventilation requirements are met by means of fan ventilation.

Extractor fans are commonly used, but e.g. in Spain there is a trend towards pressure ventilation systems linked to evaporative refrigeration (cooling systems), that enable not only ventilation but also air temperature reductions inside the building.

Throughout Europe, in farrowing and weaning houses it is common to control the indoor climate by operating automatic (sensor controlled) ventilation systems with heating of the air. The inlet of the air is usually via a central corridor (indirect) and the design of the ventilation system in the units is such that draught near the animals is avoided.

Extra local heating is applied to the piglets during their first weeks. Often, a heating lamp (gas or electric) is installed above the solid (non-slatted) lying area. The lying surface itself can also be heated by running hot water through tubes or a reservoir underneath the floor surface.

Weaners still have temperature requirements that require control of temperature and ventilation. Heating may be required during cold weather and the following heating systems are used: radiant heating-lamps, electric heating (thermal bedding with a resistance wire heating) and also hot water heating-systems (under the floor or through aerial tubes).

Heating of the housing of growing and finishing pigs is not common, as their body heat is usually sufficient to create a comfortable environment. In pens with growers, removable covers are sometimes applied to create a more comfortable lying area in the early weeks. The majority of houses for growers-finishers are naturally ventilated with air inlet directly into the pen area, but extractor fans are also used.

Some farms, located in zones where summer temperatures are extremely high, use mist evaporative cooling systems to decrease housing temperature.

2.3.2.3 Illumination of pig housing

Light requirements for pigs are laid down in Directive 91/630/EEC stating that pigs may never be permanently kept in the dark and need light comparable with normal daylight hours. Light must be available for good control of the animals and does not have a negative influence on pig production. Light can be artificial or natural entering through the windows, but additional electric light is normally applied.

Different lamps are used with different energy requirements Fluorescent light are up to seven times more efficient than filament bulbs, but they are also generally more expensive to buy. Lighting installations should conform with normalised standards for safe operation and must be water-resistant. Lights are installed in such a way that sufficient radiation (light level) is assured to allow the required maintenance and control activities.

2.3.3 Pig feeding and watering systems

2.3.3.1 Pig feed formulation

Feeding of pigs is aimed at supplying the required amount of net energy, essential amino acids, minerals, trace elements and vitamins for growth, fattening or reproduction. the composition and supply of pig feed is a key factor in the reduction of emissions to the environment from pig farming.

Pig feed formulation is a complex matter, combining many different components in the most economical way. Different factors influence the composition of a feed. Components used for feed formulation are determined by the location. For example in Spain, cereals are more commonly used inland, whereas in the coastal zones cereals may be partially replaced by cassava. It is now common that different feeds are applied enabling formulation closer to the requirements of the pig. For example, 2-phase feeding is applied for sows and 3-phase for finishers. This section can only give a short overview of the essential elements that are combined in pig feed.

An important feature of a feed is its energy content and in particular the amount of energy that is really available to the pig, the net energy. The net energy of a feed indicates the maximum amount of energy that can be stored as fat tissue and is expressed in MJ/kg.

Essential amino acids for pigs are supplied, as their metabolism cannot supply them. They are: arginine, histidine, isoleucine, leucine, lysine, methionine (+cystine), phenylalanine (+tyrosine), threonine, tryptophan and valine. Concerning the two sulphur containing amino acids, methionine and cystine, the last one is not essential, but as methionine is a precursor of cystine (two molecules of cystine produce one molecule of methionine), they are always linked. The first limiting amino acids are: lysine, methionine (+ cystine), threonine and tryptophan. To prevent deficiency, pig feed has to meet minimum requirements by selecting the right components or by adding synthetic amino acids. [172, Denmark, 2001] [201, Portugal, 2001]

The pigs' requirement for minerals and trace elements is a complex matter, even more so due to the interactions between them. Their doses in feeds are measured in g/kg (minerals) or mg/kg (trace elements). The most important are Ca and (digestible) P for bone tissue. Ca is also important for lactation and P is important for the energy system. Often their functionalities are related and so therefore attention must be given to their ratio. The minimum requirements vary for the different production stages or purposes. For early growth (including weaners) and lactation, more Ca and P is required than for growing and finishing. Mg, K, Na and Cl are usually given at levels sufficient to meet the requirements.

The requirements of trace elements are defined as minimum and maximum levels, as the elements are toxic above certain concentrations.

Important trace elements are Fe, Zn, Mn, Cu, Se and I. The requirements can usually be met, but Fe is given by injection to suckling piglets. Copper and zinc can be added to the feed ration of pigs in a quantity higher than the actual production needs in order to make use of the pharmacological effects and the positive effects on production performance (auxinic effect). However, European and national rules have been adopted, for example in Italy, regarding additives in feeds, which places limits on the addition of copper and zinc in order to reduce the quantity of these two metals in animal slurry.

Vitamins are organic substances that are important for many physiological processes, but can usually not (or not sufficiently) be provided by the pig itself and therefore have to be added to the pig's feed. There are two types of vitamins:

- fat soluble vitamins: A, D, E, K
- water soluble vitamins: B, H (Biotin) and C.

Vitamins A, D, E and K are supplied on a regular basis, but B-vitamins, H and C are supplied daily, as the animal can not store them (except B12). There are minimum requirements for the concentration of vitamins in pig feed, but the requirements of pigs are affected by many factors such as stress, disease and genetic variation. To meet the varying requirements, feed producers apply a safety margin, which means that usually more vitamins are supplied than necessary.

Other substances might be added to pig feed to improve:

- production levels (growth, FCR): e.g. antibiotics and growth promoting substances
- quality of feed: e.g. vitamins and trace elements
- technological characteristics of feed (taste, structure).

Organic acids and acid salts can be added for their effect on digestibility and to allow a better use of the feed energy.

Enzymes are substances that enhance chemical reactions of the pigs’ digestive processes. By improving digestibility, they increase the availability of nutrients and improve the efficiency of metabolic processes [201, Portugal, 2001].

Most concern about the environmental importance of feed additives in intensive animal production, is related to the use of the antibiotics, and the potential risk of the development of drug-resistant bacteria. Their application is therefore strongly regulated and registration of these substances is organised at a European level. Authorised antibiotics and growth promoters might be used through the entire growing period, as they are not considered to leave any residues in the body as their metabolites do not cross the intestinal barrier [201, Portugal, 2001].

A report has been drafted on the aspects of the use of antibiotics in the animal production sector by the European Commission, [36, EC, 1999] and summarised in a note by Dijkmans [32, Vito, 1999]. It reports that the resistance of disease-spreading bacteria against a wide range of antibiotics is a growing problem in human medical science. The growing resistance is caused by the increased application of antibiotics in human health science, in veterinary science, and as a feed additive in animal breeding and even for plant protection.

Due to the use of antibiotics in feed, antibiotic resistant micro-organisms might develop in the gastro-intestinal tract of animals. Potentially these resistant bacteria can infest humans on or in the vicinity of the farm. The genetic material (DNA) can be taken up by other bacterial human pathogens. Potential routes for infection of humans are the consumption of contaminated meat or water, or food contaminated by manure. There may also be a risk of infection of people living near the farm.

In several countries, feeding without antibiotics is carried out, such as in Sweden, which has a total ban on all feed antibiotics (including the ones authorised in the EU) and in Denmark which has a total ban on the use of antibiotics in pig feed. In other MSs proposals are under discussion for the total ban on the use of antibiotics. The true effects of antibiotics on FCRs and on manure production are not agreed internationally. Similarly the environmental effects of antimicrobials are also unknown, e.g. such as the resistance of soil and water, and the consequences for soil and water ecology. Antibiotics still might be administered directly to animals in all MSs, even although they are not used in feeds [183, NFU/NPA, 2001].

2.3.3.2 Feeding systems

There are no uniform systems practised across the whole of Europe for pig feeding. Feeding systems can be linked with the feeding practice and feeding practice is normally linked with pig production type. For example in the UK, there are weaner producers who produce pigs of 30 kg from their own sows, fatteners who buy the 30 kg pigs and finish them at about 90 kg and breeder-feeders who have their own sows, breed their own piglets and finish them at about 90 kg. [131, FORUM, 2001].

The design of the feeding installation depends on the structure of the pig feed. Liquid feeding is most common, but for example in Spain dry feeding is applied in 98 % of the farms, and mixtures are also applied. Regimes are ad libitum or restricted. For example in Italy the following variation applies [127, Italy, 2001]:

- on mating/gestating sows: 80 % of farms operate liquid feeding; the other 20 %, dry feeding
- farrowing sows and weaning piglets are (it is assumed) given dry feed
- growing/finishing pigs are liquid-fed on 80 % of farms, 5 % are fed with wetted feed, feed supplied as dry plus drinkers on 5 %, and dry-fed on 15 %.

As far as feeding systems are concerned, descriptions were given in [27, IKC Veehouderij, 1993] and [125, Finland, 2001]. The feeding system consists of the following parts:

- the feeding trough
- the storage facility
- the preparation
- the transport system
- the dosage system.

Feeding can vary from fully hand-operated to fully mechanised and automated systems. Troughs of different designs are used and provisions are made to prevent pigs lying in the trough. Feed is often delivered dry and mixed with water. Different dry feeds are purchased to allow a mixture close to the required nutrient content. Dry feed is usually transferred from the storage to the mixing machines by augers.

Liquid feeders consist of a mixing container, where the feed is mixed with water, and tubes to distribute it to the animals. The rationing of the mixture can be done automatically based on weighing the exact amounts or can be computer controlled, mixing according to the feeding plan and substituting feed when necessary. Liquid feeding can also be operated manually by weighing and mixing the required amounts.

In some loose housing for mating and gestating sows, feeding machines consist of a central feeding station detecting a label around the neck of the sow. The machine identifies the animal and supplies the required amount. The amount and supply are adjusted to allow the sow to eat as much and as often as it needs.

Distribution varies with the type of feed. Dry feed can be transported by a feeding cart or mechanically through tubes or spiral feeders in the same way as liquid feed. Liquid feed is pressed through a plastic tube system, in which the pressure is built up by the pumping system. There are centrifugal pumps, which can pump large amounts and can achieve about 3 bar. Displacement pumps have a lower capacity, but are less limited by pressure build up in the system.

The choice of feeding system is important as it can influence daily weight gain, FCR and percentage feed loss [124, Germany, 2001].

Feeding system	Daily weight gains g/day	Feed conversion kg/kg	Losses %
Dry feeding	681	3.05	3.23
Automatic mash dispenser	696	3.03	3.62
Liquid feeding	657	3.07	3.64

Table 2.8: Effect of feeding system on weight gain, FCR and feed losses [124, Germany, 2001]

2.3.3.3 Drinking water supply systems

For the supply of drinking water, a great variety of drinker systems are available. Drinking water can be obtained from deep wells or from the public supply system. The quality of the water is the same as that for human consumption. In some MSs, installations have a main reservoir with a large capacity and with possibilities for disinfecting treatment; inside each house or sector there may be smaller reservoirs to allow water distribution together with medicines and/or vitamins. Different water supply systems are used, such as pipettes, shells or canals [130, Portugal, 2001].

Drinking water can be distributed to the animals in different ways:

- by nipple drinkers in the trough
- by nipple drinkers in a cup
- by a biting nipple
- by filling the trough.

By pressing a nipple with its nose, the pig can make water run into the trough or the cup. Minimum requirement capacities vary from 0.75 – 1.0 litres per minute for piglets and 1.0 - 4.0 litres per minute for sows.

A biting nipple gives water when the pig sucks on it and opens a valve. The water will not run into a trough or cup. The capacity of the bite nipple is 0.5 – 1.5 litres per minute.

Watering the animals by filling the trough can vary between a simple tap to a computerised dosing system measuring exactly the required volume.

2.4 Processing and storage of animal feed

Many on-farm activities involve the processing and storage of feed. Many farmers obtain feed from external producers. It can be readily used or needs only very limited processing. On the other hand, some large enterprises produce the major part of the basic ingredients themselves and purchase some additives to produce the feed mixtures.

Processing of feedstuff consists of grinding or crushing and mixing. Mixing the feedstuffs to obtain a liquid feed is often done shortly before feeding the animals, as this liquid cannot be stored for a long period of time. Grinding and crushing are time-consuming and require a lot of energy. Other energy-consuming parts of the installation are the mixing equipment and the conveyor belts or air pressure generators used to transport the feed.

Feed processing and feed storage facilities are usually located as close as possible to the animal housing. Feed produced on the farm is usually stored in silos or sheds as dry cereals; gas emissions are then limited to the emission of carbon dioxide from respiration.

Industrial feed can be wet or dry. If dry it is often pelleted or granulated to allow easier handling. Dry feed is transported in tanker lorries and unloaded straight into closed silos, therefore dust emissions are usually not a problem.

There are many different designs of silos and materials used. They can be flat at the bottom to stand on the ground or conical, resting on a supporting construction. Sizes and storage capacities are numerous. Nowadays, they are often made of polyester or similar material and the inside is made as smooth as possible to prevent residues sticking to the wall. For liquid feed, materials (resins) are applied to resist low pH products or high temperatures.

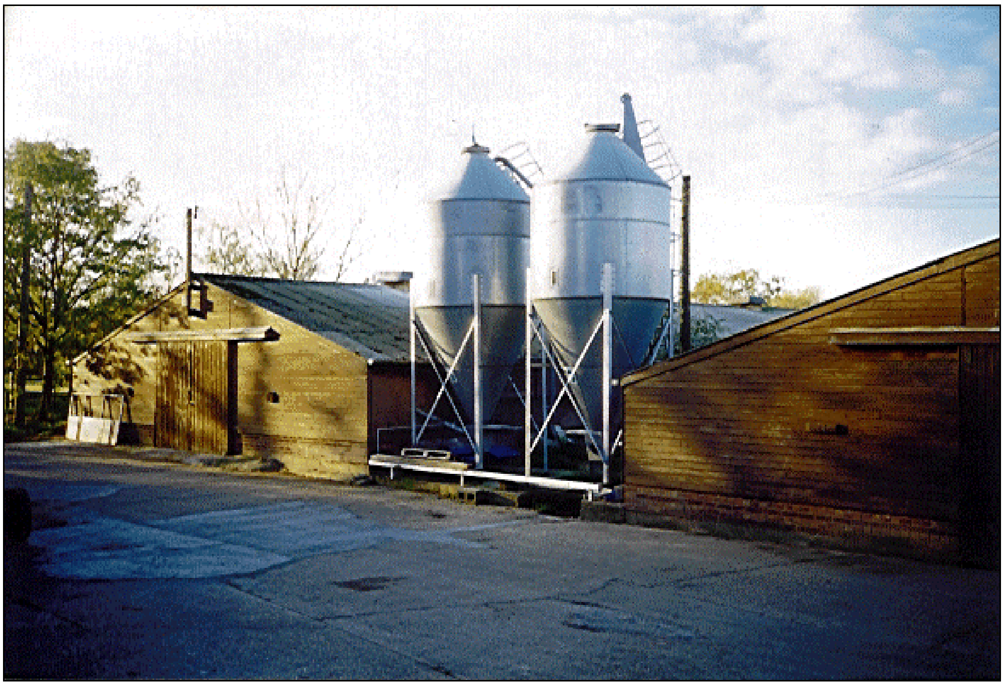

Figure 2.32: Example of silos built close to the broiler houses (UK)

Silos are usually a single construction, but (Italian) designs are on the market that can be transported in parts and assembled in the farmyard. Silos are usually equipped with a manhole for internal inspection and a device for air venting or relieving overpressure during filling. Equipment is also applied for aeration and stirring of the contents (especially soya) and to allow smooth transport of the feed out of the silo.

2.5 Collection and storage of manure

Manure is an organic material, which supplies organic matter to soil, together with plant nutrients (in relatively small concentrations compared to the mineral fertilisers). It is collected and stored either as liquid ***slurry*** or as a ***solid manure***. Manure from intensive livestock is not necessarily stored on-farm and particular care is taken in broiler units, because of the risk of spreading disease.

Slurry consists of excreta produced by livestock in a yard or a building mixed with rainwater and wash water and, in some cases, with waste bedding and feed. Slurry may be pumped or discharged by gravity.

Solid manure includes farmyard manure (FYM) and consists of material from covered straw yards, excreta with a lot of straw in it, or solids from a mechanical slurry separator. Most poultry systems produce solid manure, which can generally be stacked. Pig manure is often handled as slurry.

Slurry can be stored for long periods of time in a storage facility under the animal house, but in general inside storage is temporary and manure is regularly removed to an outside storage facility in the farmyard for further processing. Storage facilities usually have a minimum capacity to guarantee sufficient storage until further manure handling is possible or allowed (Table 2.9). For slurry storage in particular, the required capacity has to allow for minimum freeboard and for rainfall, depending on the type of slurry storage applied. The capacity depends on the climate in relation with the periods in which the application to land is not possible or not allowed in relation with the size of the farm (animal numbers) and the amount of slurry produced and is expressed in months rather than in m^3. A commonly used storage period is 6 months and large slurry tanks can easily contain 2000 m^3 or more.

EU Member State	External manure storage capacity 1) (months)	Climate
Belgium	4 – 6	Atlantic/Continental
Luxembourg	5	Atlantic/Continental
Denmark	6 – 9	Atlantic
Finland	12 (except for deep litter)	Boreal
France	3, 4 and (Brittany) 6	Atlantic
Germany	6	Continental
Austria	4	Continental
Greece	4	Mediterranean
Ireland	6	Atlantic
Italy	3 (solid manure) 5 (slurry)	Mediterranean
Portugal	3 – 4	Mediterranean
Spain	3 or more	Mediterranean
Sweden	8 – 10	Boreal
the Netherlands	6 (pig slurry) length of cycle indoors for poultry	Atlantic
UK	4 – 6	Atlantic
1) deep litter of loose-housed poultry systems is considered as storage space		

Table 2.9: Times of storage of poultry and pig manure in a number of MSs
[191, EC, 1999]

Manure can have a relatively high dm-content (dried poultry manure and litter-based manure) or can be a mixture of manure, urine and cleaning water called slurry. Facilities for the storage of manures are normally designed and operated in such a way that the substances they contain cannot escape.

The design and the material to be used often have to be chosen in accordance with specifications and technical requirements laid down in guidance notes or in national or regional regulations (e.g. Germany, UK, Belgium). The regulations are often based on water regulations and their objective is to prevent any contamination of ground- or surface water. They also include provisions for maintenance and inspection and procedures to follow in case of an escape of liquid manure which could pose a risk of damage to water resources.

Spatial planning of manure storage on-farm is regulated for protection of water sources and to protect sensitive objects in the vicinity of the farm against odour. Regulations prescribe minimum distances, depending on the number of animals and on site-specific features, such as prevailing wind direction and the type of neighbouring objects.

The following types of manure storage systems are commonly applied:

- storage for solid and litter-based manure
- slurry tanks
- earth-banked stores or lagoons.

2.5.1 Poultry manure

Most ***solid manure*** is produced in buildings and may be stored in the same building until cleared out after the production cycle, i.e.:

- approximately annually for laying hens in deep pit and deep litter systems
- every 6 weeks or so for broilers (table chickens)
- every 16 to 20 weeks for turkeys, and every 50 days for ducks.

For example, in the Netherlands the majority (89 %) of layer and poults houses have a storage capacity of 1 week, 10 % have a capacity of 1 year and 1 % of up to 3 years (deep pit systems).

Some (laying hen) egg production systems allow for more frequent, almost daily removal of manure. For free range systems, birds have access to the outside environment and some droppings will be deposited in fields.

Laying hens produce droppings with typical moisture contents of 80 – 85 %, reducing to around 70 – 75 % with regular daily mucking out. The initial moisture content is likely to be mainly influenced by nutrition, whilst the drying rate is affected by the external climate, house environment, ventilation and the manure handling system. Some systems enable manure to be dried to lower moisture contents in order to reduce ammonia emissions. Some laying hens use a litter-based system similar to broilers. In-house manure collection and storage systems are described in Section 2.2.1.

Broilers (table chickens) are typically bedded on wood shavings, sawdust or straw which, when combined with bird droppings, produces a fairly dry (around 60 % dry matter) friable manure, often referred to as poultry litter. Sometimes shredded paper is used as a bedding material. Poultry litter quality is affected by temperature and by ventilation, drinker type and management, feeder type and management, stocking density, nutrition and bird health. Systems are described in Section 2.2.2.

Turkeys are typically bedded on wood shavings to about 75 mm depth, which produces a litter of around 60 % dry matter, similar to broiler litter. Systems are described in Section 2.2.3.

Ducks are normally bedded on straw applying highest amounts in finishing accommodation. A lot of water is spilled and this results in a litter relatively low in dry matter (around 30 % dry matter). Systems are described in Section 2.2.3.

2.5.2 Pig manure

Slurry may be stored beneath fully-slatted or partly-slatted floors of livestock buildings. The storage period can be quite short but may extend to several weeks, depending on design. In-house manure collection and storage systems are described in Section 2.3. Where further storage is required, slurry is usually sluiced by gravity or pumped to collection pits and/or directly to slurry stores. In some cases a slurry tanker is used.

Where significant quantities of straw are used for bedding, ***solid manure*** is created which may be removed from buildings regularly (every 1, 2 or 3 days) or (in deep-strawed buildings) after batches of pigs are moved every few weeks. Solid manure and FYM are typically stored in concrete yards or on field sites ready for spreading to land.

Many pig farms produce both ***slurry*** and ***solid manure***. There is a tendency to collect the excreta and urine separately to reduce ammonia emissions from housing (see Chapter 4). They may be mixed again in storage if further treatment of the slurry and/or the solid manure is not required [201, Portugal, 2001].

2.5.3 Storage systems for solid and litter based manure (FYM)

Solid and litter-based manures are normally transported by frontloader or (chain) belt systems and stored on an impermeable concrete floor in the open or in closed barns. The store can be equipped with side walls to prevent slurry or rainwater leaking away. These constructions are often attached to an effluent tank to store the liquid fraction separately. The tank may be emptied regularly or the contents may be moved to a slurry store. Double storey constructions are also applied that allow the liquid fraction of manure and rainwater to drain into a basin underneath the manure storage area (Figure 2.33).

Figure 2.33: Storage of littered manure with separate containment of the liquid fraction (Italy)

Temporary field heaps are created prior to field application. They may remain in place for a few days or up to several months and should be sited where there is no risk of run-off entering watercourses or groundwater.

Only one Member State (*Finland: General Agricultural Environment Protection Scheme under their Agri-Environment Programme to which about 90 % of farmers belong*) currently requires farmers to provide a cover for such heaps.

2.5.4 Storage systems for slurry

2.5.4.1 Slurry storage in tanks

Slurries are pumped from the slurry pit or slurry channel inside the housing to an external slurry storage. Slurry is transported via a pipeline or by means of a slurry tank, and can be stored in slurry tanks above or below ground.

Slurry storage systems consist of collection and transfer facilities. Collection facilities are structural-technical facilities (channels, drains, pits, pipes, slide gates) for the collection and piping of liquid manure, slurry and other effluents, including the pumping station. Valves and sliding gates are important devices to control (back)flow. Although single valve designs are still common, double valve (sliding gate) designs are recommended for safety reasons.

The structural-technical facilities intended for homogenisation and transfer of liquid manure and slurry are called transfer facilities.

Below-ground tanks and reception pits are often used to store small amounts of slurry and can act as reception pits to collect slurry before it is pumped to a larger slurry store. They are usually square constructions built from rendered reinforced blocks, reinforced concrete made on site, ready-made concrete panels, steel panels or glass fibre-reinforced plastic (GRP). With blocks or bricks, extra attention is paid to the impermeability by applying elastic coating or lining. Occasionally, larger stores are constructed with reinforced concrete or block-work, or concrete panels; they may be above ground or partly below ground, and are often rectangular in shape. Below-ground tanks made of reinforced concrete elements with capacities up to 3000 m^3 are the most common storage for slurry in cold regions like Finland [188, Finland, 2001].

Aboveground circular stores are normally made from curved steel panels or concrete sections. Steel panels are coated to protect them against corrosion, usually by coating them with paint or a ceramic layer. Some concrete panel stores may be partly below ground. Normally all stores are built on a properly designed reinforced concrete base. In all tank designs, the thickness of the base plate and the suitability of the seal at the joint of the wall and the tank base are very important features to prevent slurry from leaking away. A typical system has a reception pit with a grid cover next to the main store. A pump is used to transfer slurry to the main store; the pump can be fitted with an extra outlet to allow slurry mixing in the reception pit. Aboveground slurry tanks are filled via a pipe with an opening above or below the slurry surface. Prior to discharge or filling, liquid manure is normally thoroughly mixed with hydraulic or pneumatic stirring systems to agitate sediment and floating matter and to obtain even distribution of the nutrients. Slurry mixing can be carried out using propellers, either mounted through the side of the store or suspended from a gantry over the top of the store. Stirring can cause sudden releases of large quantities of noxious gases and proper ventilation is required, particularly if done in housing.

The main store may have a valve outlet to allow emptying back to the reception pit, or alternatively it can be emptied using a pump located in the store (Figure 2.34).

Slurry tanks can be open or may be covered with a natural or artificial layer of floating matter (such as granulated materials, straw chaff or floating membrane) or with a firm cover (such as a canvas or concrete roof) to keep rainwater out and to reduce emissions.

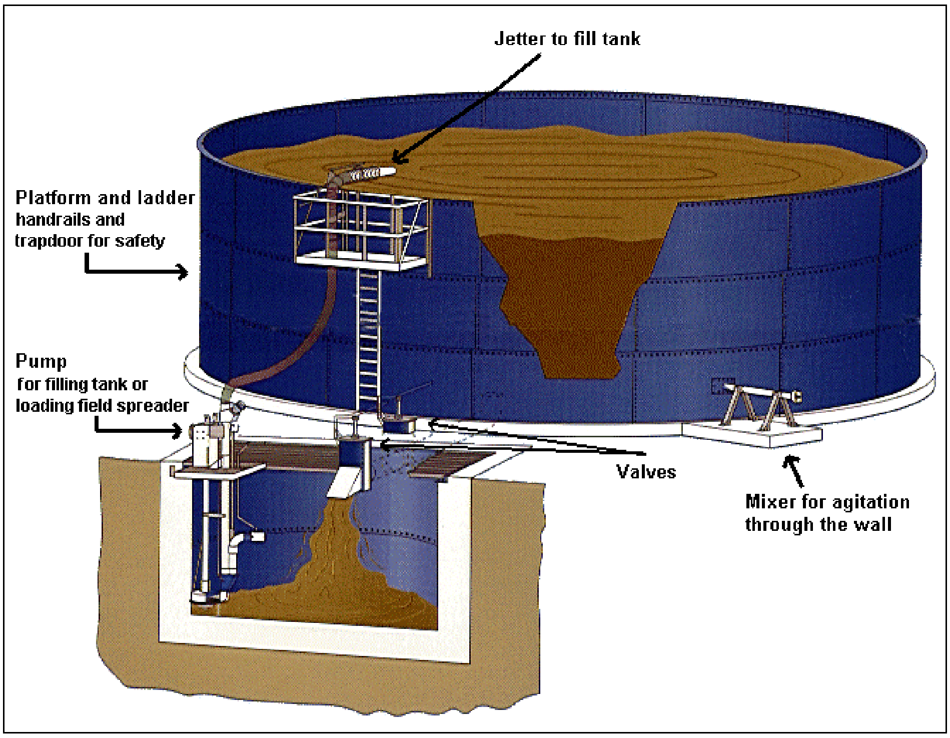

Figure 2.34: Example of aboveground slurry tank with belowground receiving pit [166, Tank manufacturer, 2000]

2.5.4.2 Slurry storage in earth-banked stores or lagoons

Earth-banked walls or lagoons are commonly applied in many MSs to store slurry for extended periods of time. Their design varies from simple ponds without any provisions to relatively well monitored storage facilities with thick plastic sheets (e.g. polythene or butyl rubber) on the bottom, protecting the soil underneath. The capacity of a lagoon depends on the slurry production of the enterprise and the operational requirements. There are no specific measures characterising a typical lagoon when it is constructed only for storage purposes [201, Portugal, 2001]. Slurry can be mixed using pumps or propellers.

The soil used to construct an earth-banked store must have special properties to ensure stability and low permeability, which usually means a high clay content. These stores are built below, above or partly-below/partly-above ground level. Earth-banked stores also include a minimum allowance for freeboard (Figure 2.35).

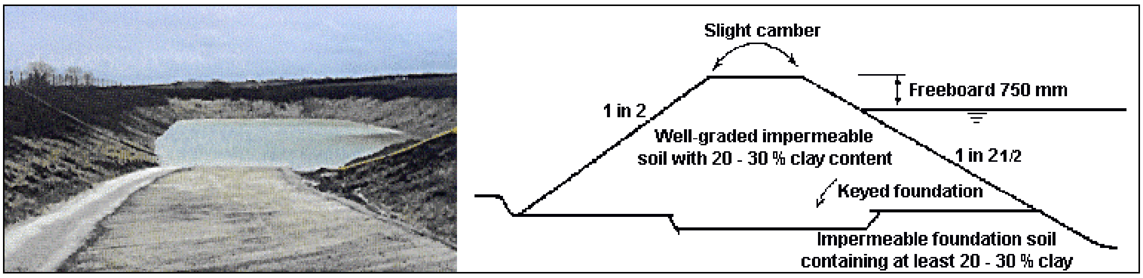

Figure 2.35: Example of earth-banked slurry store and design features [141, ADAS, 2000]

Slurry is transported by pipelines or with a vacuum tank and for this earth-banked stores can be equipped with an access ramp. The earth-banked store is often fenced off to prevent accidents.

On some farms (e.g. in Italy and Portugal) a multiple earth-banked store or lagoon system is used. In Portugal, these systems are normally designed and operated to comply with treatment requirements. Nevertheless, as the slurries have to remain in these systems for a considerable period of time, the lagoons can also serve as storage [201, Portugal, 2001]. In each store slurry is held for a certain period of time for aerobic or anaerobic degradation. Finally, slurry is removed from the last slurry store for further processing. Transport between the different stores can be mechanically or by gravity, using the natural height differences of the site.

2.5.4.3 Slurry storage in flexible bags

For the short-term storage of relatively small amounts of slurry, flexible bags are used. They may be moved from site to site (when empty). Larger bags may be sited more permanently in earthworks to provide longer-term storage. Such stores are filled and emptied by pump and the larger stores can be provided with mixer units.

2.6 On-farm manure processing

[17, ETSU, 1998], [125, Finland, 2001], [144, UK, 2000]

A number of manure treatment systems are applied, although the majority of farms in the EU are able to manage manure without recourse to the techniques listed below. Some treatments are carried out in combination. Other novel processes may still be subject to research and development or are used on only a very few farms. In some areas manure treatment is centrally organised and manure is collected from a number of farms for treatment in a communal treatment facility.

Manure treatment prior to or instead of landspreading may be performed for the following reasons:

1. to recover the residual energy (biogas) in the manure
2. to reduce odour emissions during storage and/or landspreading
3. to decrease the nitrogen content of the manure to prevent groundwater and surface water pollution as a result of landspreading and to reduce odour
4. to allow easy and safe transportation to distant regions or to other sites for application in other processes.

The latter two systems are implemented in regions with a nutrient surplus.

1. Using the energy value of manure: Organic compounds are converted to methane by the anaerobic biological digestion of manure. Methane can be recovered and used as a fuel at the farm or in the neighbourhood

2. Reduce odour emissions during storage and/or landspreading: Manure may give rise to odour nuisance during or after storage. This can in some instances be reduced by aerobic or anaerobic treatment or by additives. [174, Belgium, 2001]

3. Reduction of nitrogen content of manure: Nitrogen compounds in manure (organic, ammonium, nitrites and nitrates) can be converted to the environmentally neutral nitrogen gas (N_2). Techniques to reduce nitrogen content of manure are:

- incineration: oxidises nitrogen compounds to nitrogen gas
- biological denitrification: bacteria convert organic and ammonium nitrogen to nitrates and nitrites (nitrification) and further still to nitrogen gas (denitrification)
- chemical oxidation: supplementing manure with oxidising chemicals and increasing the temperature and pressure also results in the oxidation of nitrogen compounds

4. Processing of manure for marketing of manure compounds and/or easy and safe transportation: The water content and volume of the manure are reduced. In addition, pathogenic micro-organisms present in the manure can be inactivated (this prevents spreading of livestock pathogens to other regions), and odour emission is reduced. Sometimes different manure compounds are separated for market reasons. The following techniques are often used:

- filtration: separation of solid (most of the P) and liquid (most of the N) fractions
- ammonia stripping: after pH adjustment, NH_3 is stripped from the manure fluid and captured
- membrane filtration: after pre-filtration, reverse osmosis is used to separate nitrogen and phosphorus salts from water
- chemical precipitation: addition of MgO and H_3PO_4 results in the precipitation of magnesium ammonium phosphate
- evaporation: liquid manure is heated or depressurised, vapours are condensed and further treated
- drying: solid manure is dried by ambient air or animal body heat (see also Section 4.5), by burning fossil fuels or by burning biogas from manure fermentation
- lime treatment: increasing the pH results in the separation of NH_3, an increase in temperature and a volume reduction
- composting: the volume of the solid pig manure fraction or poultry manure is reduced and many pathogens are inactivated by biological degradation of organic material. (Compost of poultry litter is, for example, used in the mushroom industry in Ireland)
- pelletising: dried manure may be converted to fertiliser pellets.

In the following sections some of the treatment techniques are discussed in more detail.

2.6.1 Mechanical separators

Mechanical separation is used on some pig farms to convert raw slurry into separated fibre/solids (ca. 10 % by volume) and a separated liquid (ca. 90 % by volume). A wedge wire run-down screen or vibrating screen produces solids of about 8 – 10 % dry matter. Separators, which press and squeeze slurry against a fabric belt or perforated stainless steel screen, produce solids ranging from 18 – 30 % dry matter. Other techniques are sedimentation, centrifugation or membranes. Occasionally, separation is enhanced by the use of chemical flocculants. Generally, the liquids produced by mechanical separation are more easily managed during storage and handling than raw slurry. (Separation is practised in many countries, but especially in Italy where, in some regions, there is a requirement to separate pig slurry).

Composting can be applied afterwards to enhance the value of the solid product. Aerobic treatment can be applied to further reduce nitrogen surplus in the remaining liquid fraction or this fraction is applied to land without further treatment.

2.6.2 Aerobic treatment of liquid manure

On some pig farms, aerobic treatment is used to reduce odour emissions from pig slurry and, in some cases, to reduce its nitrogen content. Liquid manure is composted by means of aeration (liquid composting) or by mixing it with an adequate amount of litter. The mixture can then be composted in a stack or drum. In aeration, aerobic treatment is used to improve the properties of liquid manure without drying and solidifying the manure. Manure contains large quantities of nutrients for plants and micro-organisms, as well as microbes that are capable of utilising these nutrients. The air conducted into liquid manure starts aerobic decomposition, which produces heat, and as a result of the aeration bacteria and fungi which use oxygen in their metabolism multiply. The main products from the activity of micro-organisms are carbon dioxide, water and heat.

Designs are site-specific and take into account loading rate and the time treated slurry needs to be stored before being applied to land. Such systems may include the use of mechanical separators. (France, particularly Brittany, has some treatment plants for reducing N and P, while many countries have a few examples of aerobic treatment for reducing odour e.g. Germany, Italy, Portugal and the UK). Aeration is also applied to prepare slurry for it to be used to flush gutters, tubes or canals under slatted floors.

2.6.3 Aerobic treatment of solid manure (composting)

Composting of solid manure is a form of aerobic treatment which can occur naturally in farmyard manure heaps. High porosity (30 – 50 %) is required for sufficient aeration. Temperatures in the compost heap are between 50 and 70 ºC and kill most of the pathogens. Compost with a dry matter of up to 85 % can be produced.

Suitability for application depends on the structure of the manure, but requires a minimum dry matter content of 20 %. Typical FYM heaps do not satisfy the requirements for thorough composting. With controlled application, manure is composted in stacks of a size that suits the aerobic conditions and the use of machinery. Best results are obtained by using well-chopped straw and solid manure in the right proportions and by controlling temperature and moisture content in long narrow ‘windrows’. Composting can also be performed in a barn (e.g. pre-dried poultry manure). Specific systems have been developed that consist of a combination of tanks with aeration and stirring equipment to enhance the fermentation process and containers or boxes for further fermentation and drying.

Properly composted solid manure significantly reduces the volume of material spread to land and the amount of odour released. For easier handling, pelletising is applied in addition to composting.

2.6.4 Anaerobic treatment

Anaerobic digestion is used on some pig farms to reduce odour emissions from slurry. The process is carried out in a biogas reactor in the absence of oxygen. Processes can vary with temperature, process management, operating time and substrate mixing. In practice, the mesophilic process (at 33 – 45 °C) is most common. The thermophilic process is applied in large reactors.

The final products of digestion are biogas (approximately 50 – 75 % methane and 30 – 40 % carbon dioxide) and a stabilised treated slurry. The biogas can be used for heating, or for generating electricity. Application may include the use of mechanical separators, usually after digestion.

2.6.5 Anaerobic lagoons

This treatment is applied for pig slurry in warmer climates (e.g. Greece and Portugal). In Greece all pig slurry must be treated to comply with certain legal conditions, whereas in Portugal legal conditions only apply to discharges to watercourses). The treatment system may involve mechanical separation of the solids and subsequent separate treatment of solids and liquids. The liquid is put in a settling basin or lagoon, and overflows or is pumped into the anaerobic lagoon system (often 3 to 5 earth-banked structures). The lagoons serve as a storage for waste water as well as for the biological treatment. Designs are site-specific: for example, in Italy, covers are used to collect biogas.

2.6.6 Pig manure additives

[196, Spain, 2002]

Under the generic denomination of manure additives are a group of products made up of different compounds that interact with the manure, changing its characteristics and properties. These products are applied to the pig manure in the pits, and the following effects are described to different degrees in the label of every product:

1. a reduction in the emission of several gaseous compounds (NH_3 and H_2S)
2. a reduction of unpleasant odours
3. a change in the physical properties of the manure to make easier its use
4. an increase in the fertilising value of the manure
5. a stabilisation of pathogen micro-organisms.

Usually, the items 2 and 3 are the main reasons for their use at a farm level. Below the techniques 1 – 5 are detailed.

1. additives for reducing the emission of several gaseous compounds: The decrease in gaseous emissions achieved through its use (mainly NH_3 and H_2S) is one of the most interesting yet controversial points. Its has been well documented that up to 90 % of the N produced by the pigs is as urea. When the urease produced by faecal micro-organisms comes into contact with urea, the following reaction occurs:

$$CO(NH_2)_2 + 3\ H_2O \rightarrow 2\ NH_4 + HCO_3^- + OH^-$$

This reaction is highly influenced by temperature and pH, for example, under 10 °C or at a pH below 6.5 the reaction stops.

2. additives for reducing unpleasant odours: Odour results from the mix of different compounds under anaerobic conditions. More than 200 substances involved have been identified, such as:

- volatile fatty acids
- alcohols (indol, skatole, p-cresol, etc)
- H_2S and derivatives
- ammonia
- other N compounds (amines and mercaptans).

There is a huge variation in the proportion and concentration of every substance depending on the type of farm, nutrition and nutritional management, and climatic conditions. This could explain why in many instances the effectiveness of these compounds against odours could not be proven under farm conditions.

3. additives for changing the physical properties of the manure: The objective of the additive is to make the manure easier to handle. These additives are probably the most used and their effects are well known. Their use results in an increase in manure flowing, an elimination of superficial crusts, a reduction of solved and suspended solids and a reduction in the stratification of the manure. However, these effects were not demonstrated in every comparable case.

Their application might make the cleaning of the manure pits easier, and thereby might shorten the cleaning time required and allow a saving in water and energy consumption. Moreover, since the manure is more homogeneous, it eases the manure's agricultural use (better dosing).

4. additives for increasing the fertilising value of the manure: This effect is in fact derived from the reduction in NH_3 emissions, thereby keeping this N retained in the manure (in many cases through the increased synthesis of the microbial cells, giving higher levels of organic N).

5. additives for stabilising pathogens micro-organisms: There are many different micro-organisms in manure, part of these contribute to the gaseous emissions and odours. It is also possible to find faecal coliforms and Salmonella and other pig pathogens, virus, eggs of flies and nematoda in the manure.

Usually, the longer the storage period the higher the decrease in pathogens, because of the different requirements of temperature and pH. The pH decreases within the first month of storage (from 7.5 to 6.5 because the microbial synthesis of volatile fatty acids) which has a negative effect on pathogens survival. Some of the manure additives have been designed to control them, especially the eggs of flies.

Types of manure additives

- **masking and neutralising agents:** These are a mix of aromatic compounds (heliotropin, vanillin) that work by masking the manure odour. The agent is easily destroyed by manure micro-organisms. Its actual efficacy is questionable.

- **adsorbers:** There are a large number of substances that have demonstrated an ability to adsorb ammonia. Some types of zeolites called clinoptilolites have shown the best effect, being added either to the manure or to feed on ammonia emission. They are also able to improve soil structure and have the added benefit that they are not toxic or hazardous. Peat gives similar results and is also sometimes used.

- **urease inhibitors:** These compounds stop the reaction described earlier preventing urea from being transformed into ammonia. There are three main types of urease inhibitor:

    1. <u>phosphoramides:</u> applied directly to the soil. Show a good effect. They work better in acid soils, but could affect soil micro-organisms
    2. <u>yucca extracts (Y. schidigera):</u> many trials have been done to assess its potential but the available information is controversial, showing good results in some cases, but no effect at all in other cases
    3. <u>straw:</u> considered as an adsorbant in many references. However besides the absorbing effect, it also increases the C:N ratio. Its use is controversial because in many other works it shows an increase in ammonia emissions.

- **pH regulators:** there are two main types:

    1. <u>acid regulators:</u> usually inorganic acids (phosphoric, hydrochloric, sulphuric). In general they show good effects but their costs are very high and the substances themselves are dangerous. Their use is not recommended at farm level
    2. <u>Ca and Mg salts:</u> these salts interact with manure carbonate, decreasing the pH. They could increase the fertilising value of the manure but could also increase the salinity of the soil (chlorides). They are used sometimes, but mainly in combination with other additives.

- **oxidising agents:** Their effects are through:

    - oxidation of the odour compounds
    - providing oxygen to aerobic bacteria
    - inactivating the anaerobic bacteria that generate odorous compounds.

The most active are strong oxidising agents such as hydrogen peroxide, potassium permanganate or sodium hypochloride. They are hazardous and not recommended for farm use. Some of them (formaldehyde) could be carcinogens. Ozone application has demonstrated its efficacy but operational costs are very high.

- **flocculants:** are mineral compounds (ferric or ferrous chloride and others) or organic polymers. Phosphorus is highly decreased but their use generates waste that is difficult to manage

- **disinfectants and antimicrobials:** chemical compounds that inhibit the activity of the micro-organisms involved in odour generation. They are expensive to use and with sustained use an increase in dosing is needed

- **biological agents:** these can be divided into:

1. enzymes: their use is to liquefy solids. They are not hazardous. The actual effect depends strongly on the type of enzyme, the substrate and a proper mixing
2. bacteria:
   - exogenous strains: they have to compete with natural strains which makes getting good results more difficult. Their use is better in anaerobic pits or lagoons to reduce the organic matter producing CH_4 (sowing of methanogens bacteria is more efficient and sensitive to pH and temperature). High efficacy but frequent re-sowing has to be carried out
   - promote natural strains: this is based on adding carbonate substrates (increased C:N ratio). Its effect is based on the use of ammonia as a nutrient, but they need a sufficient source of C to develop an efficient synthesis process, changing ammonia on the organic N of cell tissue. Re-sowing has to be carried out too, to avoid reverting to the starting point. They are not hazardous and no significant cross-media effects have been reported.

Overall efficacy of manure additives and farm use: Nowadays there are many manure additives in the market, but the efficacy has not been demonstrated in every case. One of the main problems is the lack of standard techniques to test and analyse the results. Another problem with their use is that many trials have only been developed under experimental conditions in laboratories and not on-farm, where big variations in nutrition, the management of nutrition, pH and temperature can be found. Besides this, there is also sometimes a huge volume of manure to be mixed with the additive in a pit or lagoon, and the results achieved often depend a lot more on the mixing efficiency than on the lack of efficacy of the additive. Improving the flow characteristics seems to be strongly related with a good mixing.

The efficacy of every compound is highly dependent on the correct dosing, right timing and a good mixing. In some cases a small effect has been observed of an increase in the fertilising value, but this effect is related to the type of crop, the time of application and dosing.

It has to be highlighted that in many cases the effects on human or animal health or other environmental effects by using additives are not known and this, of course, limits their applicability.

2.6.7 Impregnation with peat

Liquid manure can be converted into solid manure by mixing it with peat. There are mixers for this purpose, which makes this method quite usable in practice. Straw or sawdust can also be used as litter material, but Finnish work has shown that peat absorbs water and ammonia more efficiently, and also prevents the growth of harmful microbes. This method has been recommended especially on farms in Finland, where the storage capacity of the liquid manure tank is not adequate to accommodate all the liquid manure produced but where building a new tank is not considered profitable. Peat manure is good soil improvement material for soil that is poor in humus. Liquid manure mixed with peat produces fewer odours than liquid manure alone, here the carefully mixed liquid manure is pumped into a machine which mixes liquid manure with peat into litter manure.

2.7 Manure application techniques

A range of equipment and techniques are used to spread slurry and solid manure to land. These are described in the following sections. Currently much of the slurry is applied to land using machinery which broadcasts the material across the width of spread by throwing it into the air. In some countries (e.g. the Netherlands) the use of band spreaders and injectors for slurry is required to reduce emissions. Solid manures are broadcast after being chopped or shredded into smaller pieces. Sometimes manure is incorporated into soil by ploughing, discing or using other suitable cultivation equipment. Contractors are often used for manure spreading and manure is not always spread on the producer's own land.

Nitrate from agricultural land is the main source of nitrate in rivers and aquifers in Western Europe. High levels of nitrate in certain waters have given rise to environmental and health concerns which are reflected in the EC Nitrate Directive (91/676/EEC), which is aimed at reducing nitrate pollution from agriculture. MSs are required to designate Nitrate Vulnerable Zones and draw measures under an 'Action Programme'. The measures include nitrogen limits for organic manures, closed periods when some manures (high in available N) cannot be spread to grassland and arable land (on sandy and shallow soils), and the identification of other situations when manures should not be applied. In Ireland P-load is used as a limiting factor as well.

Many countries have other legislation governing the landspreading of manures to try and balance the amounts applied with the nutrient requirements of the crop (e.g. the Netherlands - Minerals Accounting System, Denmark - compulsory annual fertiliser plans; and Ireland - nutrient management plans required under Integrated Pollution Control licensing for pig and poultry units). In some cases this is for specific regions but variations can occur (Belgium, Germany and Italy). In many countries manure spreading is not allowed during certain periods in the autumn and winter seasons. Some countries (e.g. Italy, Portugal and Finland) have specific limits on livestock densities expressed in livestock units per hectare.

Landspreading is further regulated by limiting it to certain periods of the year or to maximising it in other periods, e.g. manure application is usually at its maximum in the autumn period after harvesting. In some cases landspreading in spring can be advisable.

In other countries and areas where landspreading is not controlled by specific legislation, reliance is placed on advice, often in published guidelines such as 'Codes of Good Practice' (the UK).

If properly applied, landspreading of manure has benefits in terms of saving mineral fertiliser, improving arid soil conditions as a consequence of the addition of organic matter, and in reducing soil erosion. It is complex to control and regulate manure application, as on many occasions the farmer who has an intensive livestock enterprise may not own the receiving land. However, landspreading is environmentally important because of its potential for odour and ammonia emission during spreading and for emissions of nitrogen and phosphate to soil, groundwater and surface water. Energy consumption of the spreading equipment could also be considered. Application techniques and equipment, which are detailed in the following sections, vary depending on:

- type of manure (slurry or dry manure)
- land use
- structure of the soil.

2.7.1 Slurry transport systems

There are four main types of slurry transport systems used in Europe and that can be used in combination with different slurry distribution systems. The features of these transport systems are set out in Table 2.10 and listed below:

2.7.1.1 Vacuum tanker

- the slurry is sucked into the tanker by using an air pump to evacuate the air from the tank to create a vacuum; the tanker is emptied using the air pump to pressurise the tanker, thereby forcing the slurry out
- can be used for most slurry transport jobs; versatile applicability.

2.7.1.2 Pumped tanker

- the slurry is pumped into and from the tanker using a slurry pump, either a centrifugal (e.g. impeller type) or positive displacement pump (PD pump), such as lobe type pump
- generally have better spreading precision (m^3 or tonnes/ha) than vacuum tankers
- PD pumps require more maintenance.

2.7.1.3 Umbilical hose

- the slurry is fed by a drag hose to the distribution system, fitted to the tractor; the hose is supplied with slurry usually directly from the slurry store by a centrifugal or positive displacement pump
- possible crop damage as hose drags across the ground; hose damage and wear can be a problem on abrasive or flinty ground
- tends to be used where high application rates are applicable and on wetter soils where heavier machinery would mark land (with increased potential for run-off).

2.7.1.4 Irrigator

- this is a self-propelled machine with flexible or reeled-in hoses usually fed from a network of underground pipes, with a centrifugal or positive displacement pump, situated near the slurry store
- suitable for semi-automatic operation, but anti-pollution safeguards needed (e.g. pressure and flow switches)
- irrigators tend to be associated with high application rates.

Features	Transport system			
	Vacuum tanker	Pumped tanker	Umbilical hose	Irrigator
Range of dry matter	Up to 12 %	Up to 12 %	Up to 8 %	Up to 3 %
Requires separation or chopping	No	No (centrifugal) Yes (PD pump)	No (centrifugal) Yes (PD pump)	Yes
Work rate	➜➜➜	➜➜	➜➜	➜➜ (depends on field size/shape)
Accuracy of application rate	✓	✓✓ (centrifugal) ✓✓✓(PD pump)	✓✓ (centrifugal) ✓✓✓(PD pump)	✓✓
Soil compaction	▼▼▼	▼▼▼	▼▼	▼
Capital costs	€	€ (centrifugal) € € (PD pump)	€ € €	€ €
Labour requirement per m^3	🚹🚹🚹	🚹🚹🚹	🚹🚹	🚹
Number of arrows, ticks etc. indicates input level or value, e.g. irrigator requires low labour input				

Table 2.10: Qualitative comparison of characteristics of four slurry-transport systems [51, MAFF, 1999]

2.7.2 Slurry application systems

2.7.2.1 Broadcast spreader

A distribution system is used to bring the slurry onto the land. A widespread technique to landspread manure is the combination of a tractor with a tank with a spreading device at the rear. The broadcast spreader can be considered as a reference system (Figure 2.36). The untreated slurry is forced under pressure through a discharge nozzle, often onto an inclined splash plate to increase the sideways spread.

Figure 2.36: Example of a broadcast spreader with a splash plate [51, MAFF, 1999]

Figure 2.37 shows a hose-reel irrigator with a 'raingun' attached to a moveable trolley, which is also a broadcast spreader. The trolley is pulled out to about 300 metres with its supply pipe and is wound back to the reel (using the supply hose) where it automatically shuts off. Dilute slurry is pumped to the hose-reel from the slurry lagoon via a main pipe – often buried underground and with valved outlets in a number of places in the field. The applicator in this picture is the 'raingun' that operates at a high connection pressure. [220, UK, 2002]

Figure 2.37: Example of a raingun
[220, UK, 2002]

Broadcasting can also be operated with a low trajectory and at a low pressure to produce large droplets, to avoid atomisation and wind drift. Figure 2.38 shows a tractor applying dilute pig slurry (in April) through a boom with 2 splash plates in a crop of winter wheat. The slurry is supplied to the tractor/boom using an umbilical hose from the slurry lagoon. It is possible to apply slurry to winter wheat crops at later dates than April. In Suffolk, England, pig slurry is often very dilute and will run-off the crop onto the soil; therefore leaf scorch is not an issue.

Figure 2.38: Example of a broadcast technique with low trajectory and low pressure
[220, UK, 2002]

Figure 2.39 shows the same type of boom applicator with 2 splash plates, but this time on the back of a tractor and tanker combination, applying slurry to winter wheat in Hampshire, England. Slurry is supplied from the tanker and is spread, again, with a low trajectory and at low pressure.

Figure 2.39: Example of a broadcast technique with low trajectory and low pressure
[220, UK, 2002]

2.7.2.2 Band spreader

Band spreaders discharge slurry just above ground level in strips or bands through a series of hanging or trailing pipes attached to a boom. The band spreader is fed with slurry from a single pipe, it thus relies on the pressure at each of the hose outlets to provide an even distribution. Advanced systems use rotary distributors to proportion the slurry evenly to each outlet. The width is typically 12 m with about 30 cm between bands.

The technique is applicable to grass and arable land, e.g. for applying slurry between rows of growing crops. Because of the width of the machine, the technique is not suitable for small, irregularly shaped fields or steeply sloping land. The hoses may also become clogged if the straw content of the slurry is too high.

Figure 2.40: Example of a band spreader fitted with rotary distributor to improve lateral distribution
[51, MAFF, 1999]

2.7.2.3 Trailing shoe spreader

This is a similar configuration to the band spreader with a shoe added to each hose allowing the slurry to be deposited under the crop canopy onto the soil. This technique is mainly applicable to grassland. Grass leaves and stems are parted by trailing a narrow shoe or foot over the soil surface and slurry is placed in narrow bands on the soil surface at 20 – 30 cm spacings. The slurry bands should be covered by the grass canopy so the grass height should be a minimum of 8 cm. The machines are available in a range of widths up to 7 – 8 m. Applicability is limited by size, shape and slope of the field and by the presence of stones on the soil surface.

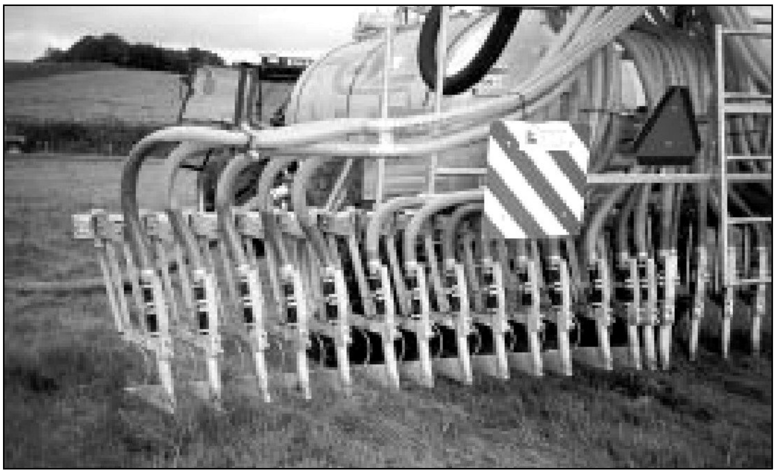

Figure 2.41: Example of a trailing shoe spreader
[51, MAFF, 1999]

2.7.2.4 Injector (open slot)

Slurry is injected under the soil surface. There are various types of injector but each fits into one of two categories; either open slot shallow injection, up to 50 mm deep; or deep injection over 150 mm deep.

This technique is mainly for use on grassland. Different shaped knives or disc coulters are used to cut vertical slots in the soil up to 5 – 6 cm deep into which slurry is placed. The spacing between the slots is typically 20 – 40 cm, with a working width of 6 m. The application rate must be adjusted so that excessive amounts of slurry do not spill out of the open slots onto the soil surface. The technique is not applicable on very stony soil nor on very shallow or compacted soils, where it is impossible to achieve uniform penetration of the knives or disc coulters to the required working depth.

Figure 2.42: Example of an open-slot shallow injector
[51, MAFF, 1999]

2.7.2.5 Injector (closed slot)

This technique can be shallow (5 – 10 cm depth) or deep (15 – 20 cm). Slurry is fully covered after injection by closing the slots with press wheels or rollers fitted behind the injection tines. Shallow closed-slot injection is more efficient than open-slot for decreasing the ammonia emission. To obtain this added benefit, soil type and conditions must allow effective closure of the slot. The technique is, therefore, less widely applicable than open-slot injection.

Deep injectors usually comprise a series of tines fitted with lateral wings or 'goose feet' to aid lateral dispersion of slurry in the soil so that relatively high application rates can be achieved. Tine spacing is typically 25 – 50 cm, with a working width of 2 – 3 m. Although ammonia abatement efficiency is high, the applicability of the technique is severely limited. The use of deep injection is restricted mainly to arable land because mechanical damage may decrease herbage yields on grassland. Other limitations include soil depth and the clay and stone content, the slope and a high draught force requiring a large tractor. Also in some circumstances there is a greater risk of nitrogen losses as nitrous oxide and nitrates.

2.7.2.6 Incorporation

Incorporation may be achieved with other equipment such as discs or cultivators depending on soil type and soil conditions. Working the manure spread on the surface into the soil can be an efficient means of decreasing ammonia emissions. The manure must be completely buried under the soil to achieve maximum efficiency. Efficiencies depend on the cultivation machinery; ploughing is mainly applicable to solid manures on arable soils. Where injection techniques are not possible or unavailable, the technique may also be used for slurries.

It is also applicable to grassland when changing to arable land (e.g. in a rotation system) or when reseeding. As ammonia losses take place quickly after spreading the manure on the surface, higher reductions in emissions are achieved when incorporation takes place immediately after spreading. At the same time incorporation will reduce the development of odour in the neighbourhood of the manured land.

To achieve incorporation immediately after spreading, a second tractor is needed for the incorporation machinery, which must follow closely behind the manure spreader. Figure 2.43 shows incorporation equipment combined with a big tanker owned by a contractor, but this combination is also possible with a smaller tanker and separate tractor. In this way the incorporation can be done together with the manure spreading in only one handling. [197, Netherlands, 2002]

Figure 2.43: Incorporation equipment combined with a big tanker
[197, Netherlands, 2002]

2.7.3 Solid manure application systems

For spreading solid manure, three main types of solid manure spreaders are commonly used:

- Rotaspreader – a side discharge spreader which features a cylindrical body and a power take-off-driven shaft (PTO-shaft) fitted with flails running along the centre of the cylinder. As the rotor spins, the flails throw the solid manure out to the side.

Figure 2.44: Example of a rotaspreader
[51, MAFF, 1999]

- Rear discharge spreader – a trailer body fitted with a moving floor or other mechanism which delivers solid manure to the rear of the spreader. The spreading mechanism can have either vertical or horizontal beaters, plus in some cases spinning discs.

Figure 2.45: Example of a rear discharge spreader
[51, MAFF, 1999]

- 'Dual purpose spreader' – a side discharge spreader with an open top V-shaped body capable of handling both slurry and solid manure. A fast-spinning impeller or rotor, usually at the front of the spreader, throws the material from the side of the machine. The rotor is fed with material by an auger or other mechanism fitted in the base of the spreader and a sliding gate controls the flow rate of the material onto the rotor.

Figure 2.46: Example of a dual purpose spreader
[51, MAFF, 1999]

2.8 Transport on-farm

The scale of transport operations on farms depends on farm size, farm layout and the location of fuel stores, feed stores and feed processing, livestock buildings, product processing (for example egg packing and grading), manure storage and fields for applying manures to land.

Feed is usually mechanically or pneumatically handled and on some pig units wet feed is pumped to feeding troughs.

Typically, tractors are used as the prime mover for manure transport and spreading, although on some pig units slurry irrigation using pumps and pipelines is practised, for example in the UK. Many farmers use contractors who typically use larger equipment and occasionally self-propelled vehicles with mounted 'spreader' bodies. Tractor-mounted slurry scrapers or loaders/grabs are used for moving manure around buildings and concrete areas, but in some egg laying systems manure is moved mechanically by belts and conveyors.
Eggs are usually mechanically handled through to packing where forklift trucks assist loading of lorries for road transport. Forklift trucks are used to transfer crates containing birds from broiler housing to road transport vehicles.

General purpose materials handlers (a specialist form of tractor) are used on some sites to undertake a variety of tasks around the farm buildings.

The movement of road transport lorries around the farm site can be extensive on large integrated egg production enterprises dealing with inputs such as birds, feed, fuel, packaging and produce output. Some sites carry out egg grading and packing for other producers.

2.9 Maintenance and cleaning

Maintenance and cleaning primarily refers to equipment and housing. Paved areas of the farm-yard can also be cleaned by sweeping or by spraying with water.

General building maintenance is necessary, including feed handling systems and other conveying equipment. Ventilation systems are checked for correct operation of fans, temperature controllers, outlets and back-draught shutters and emergency provisions. Drinking water supply equipment will be checked regularly. The provision and maintenance of appropriate conditions for keeping livestock is required to meet welfare legislation and to reduce emissions of odour.

Buildings are usually cleaned and disinfected after batches of livestock and manure have been removed. The frequency of cleaning is therefore equal to the number of production cycles per year. Typically on pig units, wash-down water enters the slurry system, but on poultry units such contaminated water is often collected separately in (below-ground) storage tanks, before being applied to land or treated in some way. Good hygiene practices are required in other building areas where product is handled and packed ready for dispatch.

For cleaning, use is often made of high-pressure washers using only water, but surface active agents are sometimes added. For disinfecting, formaline or other agents are used and they are applied with an atomiser or sprayer. This is applied if, for instance, Salmonella has been found in a flock of broilers [125, Finland, 2001].

Regular maintenance (refurbishing and repairs) and cleaning of vehicles, such as tractors and manure spreaders, can also take place. Regular checks should be made during operational periods with appropriate maintenance as described in the manufacturers' instructions. These activities usually involve the use of oil and cleaning agents and can require energy for equipment use.

Many farms have a supply of the faster wearing parts in order to effect repairs and maintenance quickly. Routine maintenance and cleaning is carried out by suitably trained farm staff but more difficult or specialist maintenance work is carried out with specialist assistance help.

2.10 Use and disposal of residues

The operation of a pig or poultry unit gives rise to a number of different residues, some of which are identified in the following list:

- pesticides
- veterinary products
- oils and lubricants
- scrap metals
- tyres
- packaging (rigid plastic, film plastic, cardboard, paper, glass, pallets etc.)
- feed residues
- building residues (cement, asbestos and metal).

Processing of manure, carcases and waste water is subject to special provisions and is dealt with in other sections of this document.

Most of the residues are paper and plastic packaging material. The most common hazardous residues are those from medicines that have been used or are past their expiring date. Small amounts of residues of cleaning material or of chemicals necessary to operate special processes (e.g. air scrubber) may be found on a farm as well.

The way in which residues are dealt with varies widely. Existing European and national legislation on environmental protection and on waste management regulate waste storage and disposal and promote the minimisation of the amount of litter and waste and the use of recyclable materials.

In general, on larger enterprises, residues can be more economically disposed of than on small farms. For collection, the residues are stored in containers or in small bins and collected by municipal or special collection services. Where no public waste collection is organised, farms may be obliged to organise collection and transportation themselves and are responsible for associated costs and treatment (Finland). Collection is difficult to organise or non-existent in remote areas.

A survey on treatment of residues on farms recently carried out in the UK gives the following picture of techniques that are used if the residues are not collected and transported off-farm [146, ADAS, 2000]:

- stockpiling
- burning in the open
- burying
- re-using.

Off-farm disposal includes disposal routes such as:

- landfilling
- storing in dustbin, included in household collection
- collecting by suppliers
- transfer to contractor.

Burning of packing material and used oils is still quite common in some MSs, whereas burning of any kind is strictly forbidden in others. In some MSs, oils are stored in purpose-designed cans/containers and are collected to be treated off-farm. Burning is also the most favoured method of disposal of all kinds of plastic products such as, covers and containers.

Veterinary residues are stored in special boxes and sometimes collected by the veterinary service, although burning and landfill occur as well.

Feed and crop residues can be mixed with farmyard manure or slurry and applied to land, or are re-used in other ways.

Tyres are dealt with in different ways, varying between collection by suppliers, and burning on farm and stockpiling.

2.11 Storage and disposal of carcases

Services to collect carcases and to process them by contractors are common. In Italy, many farms have equipment to transform carcases into liquid feed under special pressure and heating conditions [127, Italy, 2001]. Also, in other Member States the processing of carcases into feed is or has been practised, but this is now declining or completely forbidden.

Burying of carcases and open burning are still widely practised methods. In some MSs, such as the Netherlands, Germany, Denmark and France burying is strictly forbidden, but in the UK, Italy and Spain authorised burial is allowed. Some farms have an installation for incineration of carcases. This can be a quite simple burner without provision for the emitted waste gases. In the UK about 3000 small scale incinerators (<50 kg/hr) are operated, mainly on large poultry and pig farms for the incineration of animal carcases. The ash may be landfilled or disposed of by other routes.

Otherwise carcases are collected and processed elsewhere. Carcases can also be composted.

2.12 Treatment of waste water

Waste water is the water used by domestic, industrial, agricultural or other usage, and which has undergone changes in its properties as a result and is discharged. Added to this is the water from rainfall, which collects and flows away from built-on or compacted areas (precipitation water).

Cleaning water from livestock farming facilities can contain residues of dung and urine, litter and feedstuffs as well as cleaning agents and disinfectant.

Waste water, also called dirty water, originates from washing water, from facilities for personnel, from yard run-off and particularly from run-off from open concrete areas that are contaminated by manure. The amounts depend very much on the amount of rainfall. Dirty water can be managed in combination with slurry, but can also be treated and handled separately, in which case separate storage will be needed.

On poultry farms, the aim is to keep manure dry to reduce ammonia emissions and to allow easier handling. Waste water is stored in special tanks and dealt with separately.

On pig farms, waste water is commonly added to the slurry and treated in combination or applied directly to land. Various treatment systems for slurry exist and they are described in Section 2.6. On some farms in Finland using solid manure systems, waste water is conducted through a sedimentation tank into soil treatment or from production buildings into a ditch.

If kept separate, waste water (dirty water) may be applied to land through low-rate irrigators (UK) or treated in a communal or on-farm waste water treatment plant.

2.13 Installations for heat and power production

Some farms have installed solar or wind-driven generators to cover part of their own power need. Solar power supply depends very much on the weather conditions and therefore cannot serve as a main supply, but rather as an additional energy source or a replacement for energy supply aiming at a reduction of costs. Windmills attached to a generator can supply power, particularly in areas with relatively high wind-speed. The application is even more economical if excess power can be delivered to the general electricity supply network. More detailed information would be needed to assess its applicability and environmental benefits.

In some MSs much attention is given to the use of any biogas that develops during the storage and treatment of manure.

2.14 Monitoring and control of consumption and emission

In the IPPC Directive (96/61/EC), article 9.5 gives farmers a special status concerning monitoring. The article says:

> ‘The permit shall contain suitable release monitoring requirements, specifying measurement methodology and frequency, evaluation procedure and an obligation to supply the competent authority with data required for checking compliance with the permit. For installations under subheading 6.6 in Annex 1, the measures referred to in this paragraph may take account of costs and benefits.’

This text should be seen as a signal to avoid excessive monitoring obligations on pig and poultry farms.

This section gives some ideas on common practice in monitoring. However, not enough information was submitted to assess what the suitable level of monitoring at a farm is, taking into account the costs and benefits.

In some areas, farmers have to keep a register of their phosphate and nitrogen. This is usually where intensive livestock production is responsible for high pressures on the environment. The resulting balance gives a clearer indication of the input and losses of minerals on the farm. The information can be used to optimise the feeding of minerals to the animals and to the application of manure to land.

Some farmers assess the nutrient status of soils and apply an appropriate amount of organic nutrients and mineral fertiliser according to crop requirements and rotations. The level of precision varies from those who undertake soil and manure analysis and use some form of recognised nutrient management planning to those who estimate requirements using general published information or those just using experience or guesswork. The legislation that applies in some countries is described in Section 2.7, which explains that the extent of record keeping is variable.

Farmers will have records (receipts) of purchased items, although the extent to which they are kept in an organised way will vary. Such records will usually exist for the main items of feed, fuel (including electricity) and water (not all private abstractions) so the amounts used can be identified. Since feed and water are primary inputs to livestock systems their usage may be monitored by farmers irrespective of whether receipts are kept. Most poultry farmers will have bought in bedding material, whereas pig producers who use straw may produce their own or have an agreement with neighbouring farmers exchanging manure for clean straw.

Computerised registration and the administration of costs, inputs and outputs is increasing and is already common on large enterprises. Where measuring is applied, water gauges, electric meters and computers for indoor climate control are used.

There may be requirements to check slurry stores regularly for any signs of corrosion or leakage and to find any faults that need to be put right. Professional help may be required. Checking takes place after completely emptying the stores.

Regular emissions to water occur under specific legislation and within set (discharge) conditions and monitoring requirements (Portugal, Italy).

Currently, farmers do not normally monitor and control emissions to air unless specifically required to do so as a result of complaints from neighbours. These complaints are usually related to noise and odour emissions.

In Ireland, monitoring of emissions and sampling points for air (odour), noise, surface water, groundwater, soil and waste are required under Integrated Pollution Control Licensing arrangements