REDUCTION OF EXCESS SLUDGE BY APPLICATION OF SURFACE-ACTIVE SUBSTANCES – BIOCHEMICAL DESINTEGRATION

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ABSTRACT

Activation of the micro-organisms in the activated sludge process by dosing additional nutrients into the influent of the aerobic stabilisation tank, clear improvement of the biological oxygen availability as well as the lytic process of bacteria by surfactants allow to operate a municipal sewage treatment plant in theory without excess sludge production, in practice it will be reduced by up to 80 %.

INTRODUCTION

In 1996 about 2.7 million tons of sewage sludge, measured as dry solid matter, have been disposed of in Germany [Esch and Krüger, 1999]. According to Kollatsch [1998], the proportionate operating costs for sewage sludge treatment and especially for sludge disposal amount to 30 - 50 % of the total operating costs of sewage treatment plants.

BACKROUND

The activated sludge process is copied from the natural self-cleaning process of water bodies. As a result of biological composition- and degradation processes, which run in a concentrated and controlled way, the organic material contained in the waste water is absorbed and converted or respired, respectively, into biomass. The rate of organic material in waste water is higher than in natural water bodies. For its metabolization it is therefore necessary to raise the concentration of microorganisms as well as oxygen supply. Metabolization or degradation of organic material means its oxidation - burning - with the help of microorganisms. Final product of this burning process is carbone dioxide. In most municipal sewage treatment plants the oxygen necessary for the metabolism of microorganisms is fed by fine-bubble aeration into the activation tank. This type of aeration presents the advantage that due to the large surface the oxygen is well accessible for the microorganisms. It is well known that the efficiency of oxygen entry into the activation tank is influenced by the water temperature and the oxygen concentration.

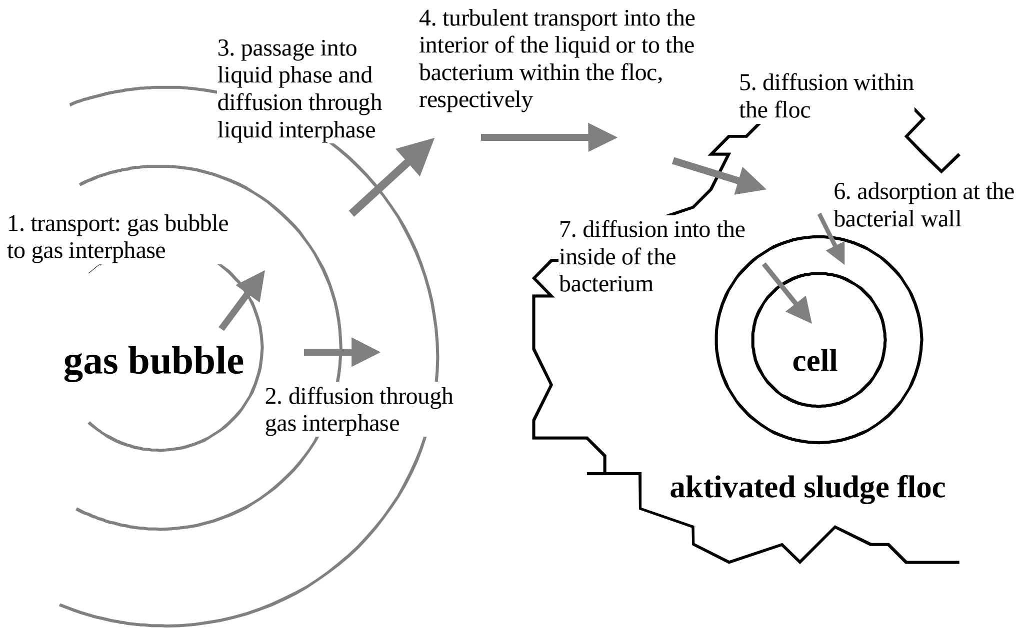

Figure 1 *Conveying distance of oxygen according to REUSS(1977), in STEINMETZ (1996)*

Figure 1 presents the individual steps of material transport from the gas bubble into the interior of the bacterium. It can be seen that the activated sludge is a multicomponent mixture and that oxygen transportation can only be described by a multiphase system (gaseous, liquid, solid). The individual transportation steps are subject to complex interrelations between bioreactions and physical transportation mechanisms. In waste water technology it is tried with the help of the so-called α-value to grasp the manifold influences of the activated sludge, i.e. the material contained in waste water, on oxygen entry. For this purpose the aeration constant under operational conditions is compared with the conditions in pure water. The studies of Steinmetz (1996) had for result that with complex waste water/sludge mixtures it is impossible to relate changes of the α-value to an individual influencing factor because the numerous chemico-physical and biological factors influence each other in a very strong way.

FRAMEWORK OF SLUDGE PRODUCTION

There is one fundamental difference between the natural biological processes occurring in the body of water and those taking place in sewage treatment plants: The sludge loading ratio in sewage treatment plants is considerably higher, due to a higher carbon charge in the inflow and a too low concentration of bacteria in the activated sludge tank, respectively. As a result there is not enough oxygen available for the biological processes, and most of the metabolism processes run rather inefficiently. The organic load of waste water is not aerated but predominantly transformed into biomass. This so-called excess sludge is continuously withdrawn from the system so that organisms with short reproduction times (bacteria) dominate. As a result the number of bacteria-consuming organisms with long reproduction times become insufficient. Dorau [1998] proposes the thesis that the biological self-optimising processes running in municipal sewage treatment plants are constantly disturbed by interference from outside, especially by excess sludge withdrawal.

COALESCENCE

In most municipal sewage treatment plants, the oxygen needed for the metabolism of the micro-organisms is fed by fine-bubble aeration into the activated sludge tank. The air bubbles produced at the bottom of the activated sludge tank are still very small. Rising towards the water surface, they unite to bigger ones, as a result of hydrostatic pressure, and thus reduce their specific surface. (see Figure 2).

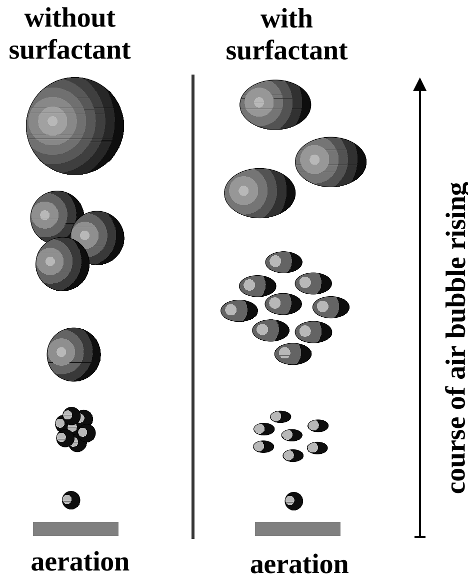

Figure 2 *Influence of surfactant on the coalescence behaviour*

This phenomenon is called coalescence; it makes itself felt the more clearly the smaller are the air bubbles originally formed [Diesterweg et al., 1978]. Besides the diminishing specific exchange surface, the coalescence rate grows with increasing bubble size [Müller et al., 1978]. This is among others the reason for the low efficiency of most aeration systems which is only 5 - 15 % related to the total oxygen quantity fed [Imhoff, Imhoff, 1993]. Moreover, the tendency towards coalescence is strongly influenced by certain material contained in the waste water [Diesterweg et al., 1978, p. 3]. But in practical operation the coalescence behaviour is often only insufficiently taken into account [Diesterweg et al., 1978].

SURFACTANTS – SURFACE-ACTIVE SUBSTANCES

According to Steinmetz [1996], under the notion *surface-active agents or surfactants* are subsumed organic compounds with a lipophilic hydrocarbon residue and a hydrophilic functional group, which due to their chemical properties reduce the surface tension of aqueous systems. The hydrophilic groups align themselves in such a way that they are in contact with the water. The lipophilic groups try to avoid the contact with water (see Figure 3). Coalescence can be changed positively by surfactants. Surfactants may differ a lot, but only few of them are suited to be applied in waste water treatment. Clear inhibition of coalescence can be reached e.g. with sodium choride [Zlokarnik, 1979 and 1980]. Steinmetz [1996] points out that the influence of surfactants on the oxygen transfer coefficient depends to a large extent on the surfactant concentration. So-called bio-surfactants are especially suited to be applied in activated sludge tanks because they are biodegradable and highly effective already in low concentrations. Bio-surfactants are lipids or lipid derivatives which are synthesised by micro-organisms during their growth phase.

Therefore only such surfactants are suited which are highly effective already in low concentrations. Surfactants have in common that they reduce the surface tension in liquid/gaseous mixtures so that the shape of the air bubbles changes. The initial globular shape becomes slightly spherical (see Figure 2).

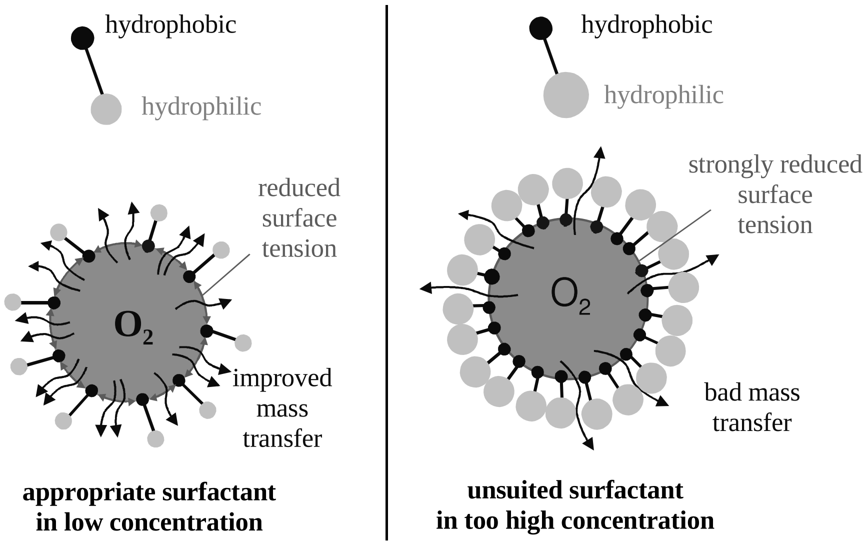

Figure 3 *Influence of surfactant on mass transfer*

In addition coalescence is delayed in time (coalescence inhibition). Thus the surface available is larger and more oxygen can go into solution. Applying surfactants oxygen use can be increased to nearly 20 %. This corresponds to an average aeration efficiency of 10 % – an increase by 100 %. Steinmetz [1996] found out that besides the material contained in waste water, biological processes - first of all metabolic processes - also clearly influence the oxygen transfer: a connection which in waste water treatment normally is ignored or only insufficiently noticed.

LYTIC PROCESSES – BIOCHEMICAL DESINTEGRATION

Besides this purely physical effect, a biochemical effect results from the addition of surfactants, which is described in the following: According to Mudrack and Kunst [1991], the nuclear zone of an activated sludge floc is surrounded by a mucilaginous matrix. Therefore only those floc parts participate actively in the aerobic purification process which not only allow dissolved pollutants to diffuse but also oxygen. In the mucilaginous matrix excreted by the bacteria, living as well as perished organisms are found. While the fringe areas of the activated sludge floc are well supplied with oxygen, oxygen deficiency is often found in its interior. Applying surfactants the matrix described is attacked, parts of the matrix break off and more floc parts are able to take part in the purification process. Perished bacteria are released and can be metabolized (see Figure 4). In addition the oxygen is able to better diffuse into the interior of the flocs.

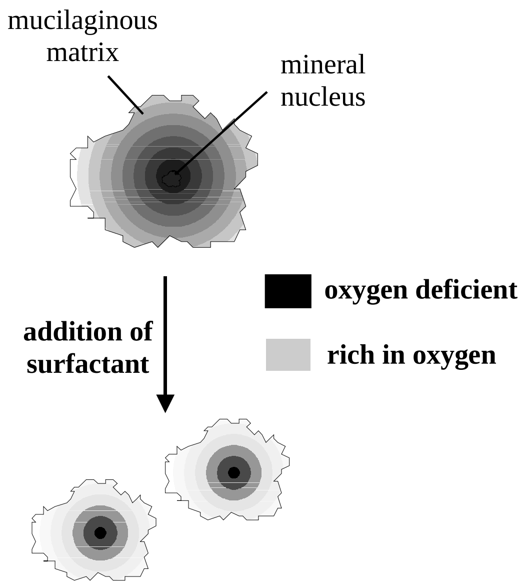

Figure 4 Influence of surfactants on activated sludge

OXYGEN PARTIAL PRESSURE AND EXCESS SLUDGE PRODUCTION

The direct dependence of excess sludge production on oxygen partial pressure is described by Hartmeier et al. [1971]. Staab [1997] points out that excess sludge production on principle depends on the sludge loading rate. According to his findings the excess sludge production is reduced due to increased oxygen partial pressure which results from lower sludge loading. Imhoff and Imhoff [1993] describe low-loaded oxidation ditches in which the organic components of the activated sludge are microbially degraded to a far-reaching extent, due to decreasing sludge loading after long aeration phases. It is generally known that with the Deep Shaft Process and utilization of pure oxygen the sludge loading and, with this, the excess sludge volume are reduced, compared to conventionally aerated activated sludge plants [Hansen et al., 1996; Hegemann, 1974].

While the fringe areas of an activated sludge floc are well supplied with oxygen, a deficiency of oxygen is often found in its interior. Excess sludge production directly depends on the oxygen partial pressure. Increasing the oxygen availability in the activated sludge tank results in higher oxygen partial pressure so that the deeper layers of the activated sludge floc, too, are sufficiently supplied. The inside layers also take part in aerobic decomposition and increase the potential for aeration of endogenous substances (see Figure 5).

Besides oxygen supply and temperature, the growth rate or the activity of the microorganisms, respectively, are influenced by nutrient supply. For optimal cell growth it is decisive that nutrients are available in a certain ratio, e.g. nitrogen : phosphorus = 10:5 [Mudrack, Kunst, 1991], and that a sufficient quantity of trace elements is present. Therefore addition of selected nutrients allows to promote aerobic bacterial populations and thus to dominate anaerobic microorganisms [Schlegel, 1992].

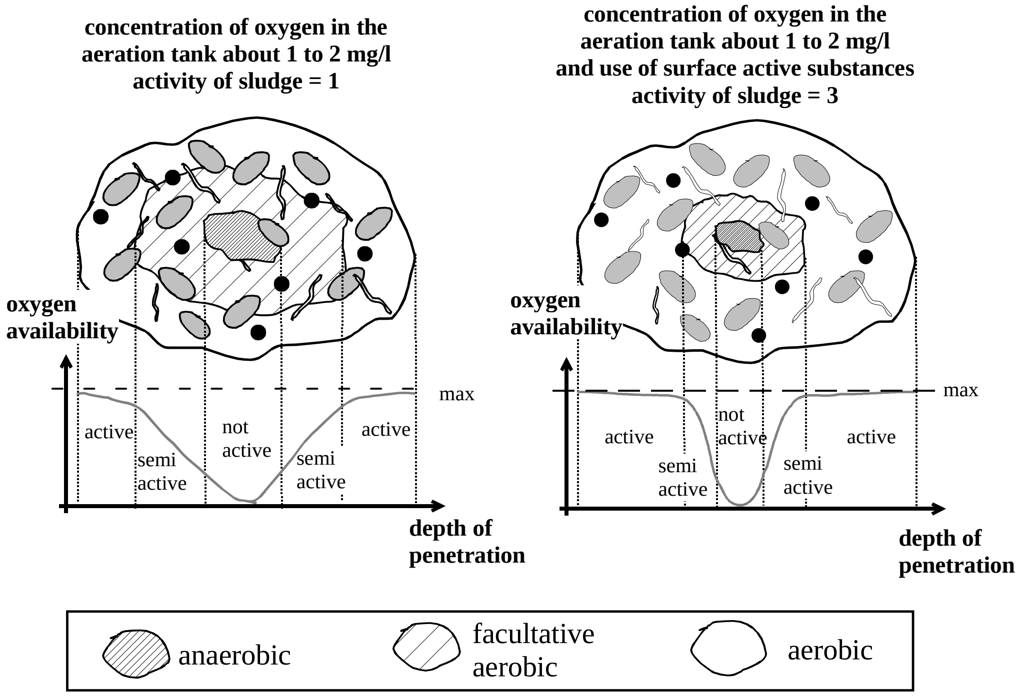

Figure 5 Influence of surfactants on the oxygen availability of activated sludge

APPLICATION OF THE EXCESS SLUDGE REDUCTION PROCESS

Using surfactants, it is possible to modify coalescence in a positive way and thus to considerably increase biological oxygen utilisation. The surface available becomes larger, and more oxygen goes into solution. By surfactants the flake matrix described above is attacked, parts of the matrix as well as cells are submitted to lytic processes, and more flake portions take an active part in the purification process. The finer and smaller the activated sludge flakes are, the better oxygen is able to diffuse into the interior of the flake, even at low oxygen concentrations (see figure 5).

The excess sludge is pumped out of the return-sludge flow into the aerobic stabilisation tank (see Figure 6). Inhere die sludge is aerated and mixed with additional nutrients. The micro-organisms are stimulated by additional nutrients, so that the biological process is stimulated to adapt to the new milieu conditions.

In a circulation system surface-active substances are added and the biochemical disintegration take part in a suitable reactor. The results of the biochemical disintegration can be easily increased by a physical disintegration pre-treatment (see Figure 6).

In this way the increase of mixed liquor suspended solids in the aerobic stabilisation tank is slowed down. Optimal dosing results in a steady mixed liquor suspended solids concentration in the aerobic stabilisation tank, and, with this, nearly infinite sludge age (see Figure 6).

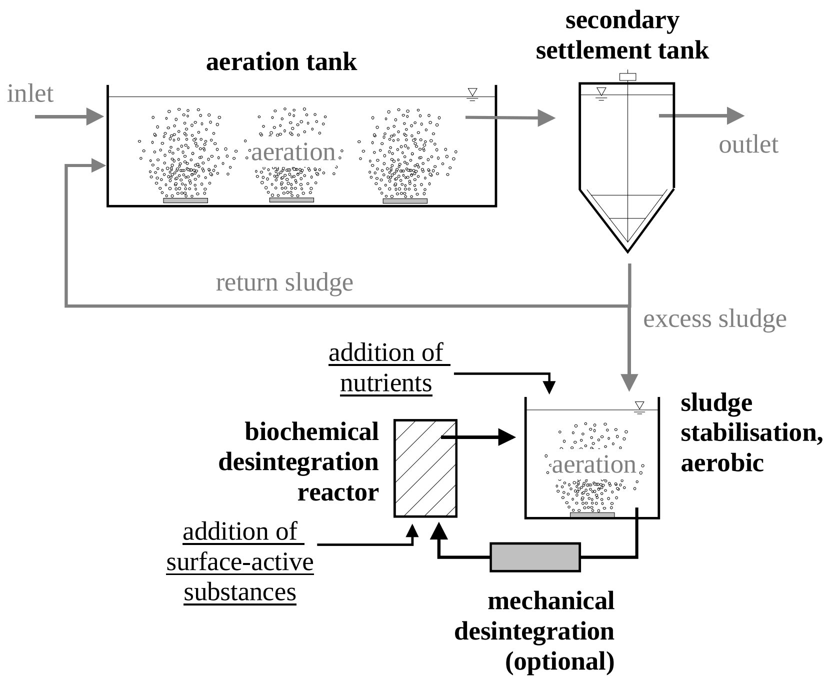

Figure 6 Process control

FINAL CONSIDERATIONS

As a result of biological metabolic processes, biomass is produced everywhere in nature. But no intact ecosystem can be found where biomass is not reintegrated into new processes, and thus a balance turns up at the long term. The more oxygen is available in the aerobic stabilisation tank, the higher developed organisms may exist there. The reasons are, besides biodiversity and balanced nutrition, such bacteria which are able themselves to produce surfactants, e.g. Microthrix parvicella [Kunst, 1999]. All phenomena described here considered, one can imagine that it might be possible to create environmental conditions – increased activity of microorganisms and considerably improved oxygen availability – which lead to metabolization of non-active and perished cells within the activated sludge. From this the conclusion can be drawn that theoretically it might be possible to run the activated sludge process without excess sludge production.

For the first time a sound process well tried in practice is available which is very well suited to reduce excess sludge production as required in a global sustainable consideration. The cost for excess sludge reduction are by about 50 – 80 % compared with thermo treatment cost in Germany, depending upon the sewage treatment plant in question.

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