High efficient and economic waste water treatment using Standardized Biological Aerated Filtration sBAF

Dr. A. Rüdiger*, Prof. Dr. I. Sekoulov **

* Albert-Lezius-Str 62, D-23562 Lübeck
** Technical University of Hamburg, Schwarzenbergstrasse 95, D-21073 Hamburg

Abstract

Biological Aerated Filtration (BAF) is a technology which is today successfully used in more than 500 European wastewater treatment plants. Biofiltration is a compact and modular aerated biological reactor which has several advantages compared with classic technologies like activated sludge with its suspended growth. The main advantages of using biofilters with fixed film biomass are the possibilities to adapt the biological treatment process to a wide range of incoming pollution loads and hydraulic variations. Due to the natural high sludge age of the biofilm in the reactor (t_S > 30 days) and the independency of the efficiency of a final settlement tank biofilters are efficient also at relative high temperatures of wastewater. The new generation of standardized biofiltration sBAF is able to treat wastewater steadily, with high efficiency (η>90%) and for lower costs compared to classical technologies.

Keywords

Waste water treatment; Biofiltration; biological filtration, nitrification

1. Introduction

The application of Biological Aerated Filtration (Biofiltration) BAF in waste water treatment goes back to the beginning of the 1980s. Since that time, filtration technology has already been used successfully as the principal unit in the treatment of potable water in order to eliminate suspended solids.

The long term positive experience regarding the application of filtration in the treatment of potable water was transferred to waste water treatment. The aim was to achieve mechanical filtration and elimination of dissolved organic and inorganic pollutants, such as BOD and nitrogen in the same reactor.

In this respect, different technologies regarding the biological filtration of wastewater were developed, such as upflow and downflow filters including or excluding aeration, as well as different filtering media like floating or non-floating media. Long term practical experiences with numerous biofiltration plants in waste water treatment has shown that BAF with granular non floating media is currently considered to be the best and most reliable technology for waste water treatment (Sekoulov, 1997).

Presently, more than 500 BAF plants are in operation in order to treat municipal and industrial waste water. The most important advantages of biological filtration are fully automatic function, very good treatment results, low space requirements, modular and flexible concept, high sludge ages and dispense of final settlement tanks.

Whereas the classical biofiltration has been developed mainly for huge municipal waste water treatment plants the new generation of standardized BAF was developed for small and medium treatment plants in the range from 2.000 to 20.000 PE.

2. Standardized Biological Aerated Filtration sBAF

2.1 General aspects

The biological filtration BAF has been developed mainly for waste water treatment in large municipal waste water treatment plants in the range between 100.000 and up to 2 Mio PE. The reasons for development and construction of large BAF plants have been the advantages of low space requirements connected with very good treatment results, modular and flexible concept. The disadvantages of classical BAF technology are higher costs compared with activated sludge technology. This costs increase significantly when the plant gets smaller. Because the classical biofiltration is not economic for small and medium sized treatment plants a new generation of standardized BAF has been developed. With this new generation the full advantages of BAF can also be used for small and medium plants (2.000 to 20.000 PE) in economic way.

2.2 Presentation of sBAF technology

The principal function scheme of sBAF is portrayed in Figure 1. The circular reactor with diameter between 3 and 4 m is filled with a granular filtering and non floating medium (expended clay 3 to 6 mm of granular size). The filtering material serves as support media for bacterial growth. In the same time the filtering medium retains the suspended solids by filtration. This results in a “two in one” reactor where elimination of organic pollution and retention of suspended solids takes place in one and the same unit.

Mechanically pre-treated raw waste water is supplied to the reactor by a feeding pump (1) from the bottom to the top (upflow). To maintain aerobic conditions and to allow aerobic bacterial growth on the material, the reactor is aerated by a compressor (2) through membrane aerators (co-current stream). Sufficient air needs to be injected into the BAF unit in order to supply enough oxygen for biological growth and nitrification. It also needs to be taken into account that the solubility of air in water decreases when the water temperature increases (Brinke-Seifferth, 1996) Equal distribution of air and water is achieved by means of distribution lances (3). Waste water cleaning is affected through biological activity and mechanical filtration. The clean water with low concentration of suspended solids of about 10 mg SS/L leaves the reactor at the top (4). A secondary clarifier is not necessary.

One sBAF module of 3,40 m of diameter for example is able to treat wastewater for about 2.500 Inhabitants in a large hydraulic range up to 90 m^3/h.

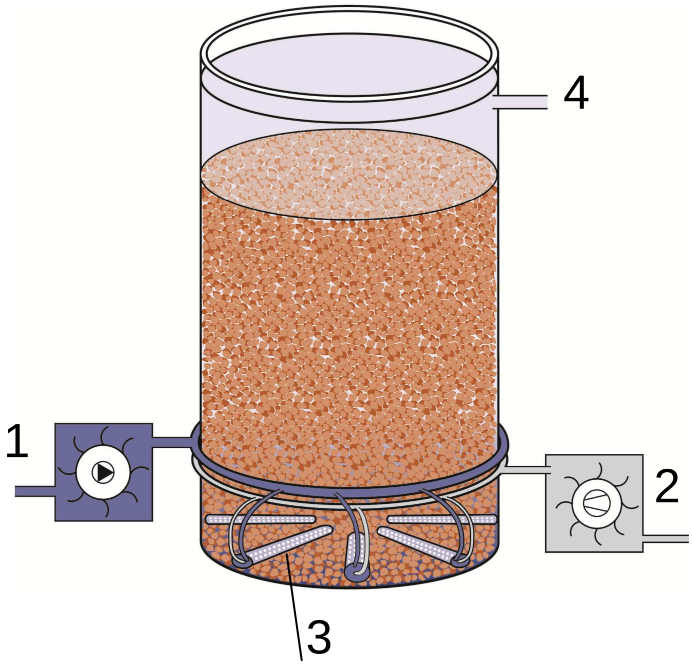

Figure 1: Scheme of Biological Aerated Filtration BAF

The physical properties like type of material, grain size and specific density of the filtering medium are of great importance to the proper functioning of biofiltration. Practical experience during operation of biofiltration plants shows that natural granular burnt clay with specific particle density (dry) in the range of about 1.300 kg/m³ is the most suitable (Sekoulov, 1996). Depending on the type of wastewater and on the targets to be achieved, grain sizes between 2 and 6 mm are used. The height of the material in the filter usually lies between 3 and 5 m. The filtering material lasts several decades. The usual annual material loss is found to be approx. 2 to 3 % pa.

As a result of the retention of suspended solids in the filter as well as bacterial growth, a limiting headloss occurs across the filter bed after a certain operation period. At that point, the filtration phase is completed and the filter needs to be backwashed in order to remove the suspended solids. The headloss at the moment of backwashing amounts to approx. 40 to 80 mbar/m, depending on the filtering media used. Backwashing is implemented as a combined air/ water flushing without fluidization of filter bed. After several minutes of air washing only, the filter will be washed using air and water. The final step consists of pure water washing. Backwashing requires approx. 30 to 40 minutes and is usually realized automatically once a day. The amount of water required for backwashing lies within 3 to 5 % of the total treated water.

Considerable savings can be made in volume and space using BAF. For example, the space required for a municipal sewage plant can be cut down to 25% compared to that required for activated sludge plants or SBR plants according to A 1 31 (Rüdiger, 1999). The low space requirement for BAF plants makes a fully covered in-house treatment plant economically possible. In this case the WWTP can also be constructed close or even inside villages and towns or in tourist areas.

3. BAF in relation to conventional technologies

One of the main engineering tasks in planning of waste water treatment plants is to realize the best choice of treatment technology. This choice takes place in the first project phase followed by several months of detail studies and engineering. *Activated sludge technology* is today widely used for waste water treatment especially in Europe and Northern Countries. In order to avoid a separate secondary settlement tank and to reduce the investment costs, *Sequencing Batch Reactors SBR* as a variance of activated sludge systems have been developed in the years about 1970. This technology is today in use mostly for medium sized treatment plants.

One of the main operational disadvantages of the activated sludge technologies are problems with sludge settlement in the secondary clarifier. International research investigations have shown that about 80% of al activated sludge plants have at least temporary problems with sludge settling (Tandoi et al, 2006)

Rising sludge and filamentous bulking are often observed in activated sludge systems. Rising sludge is caused by denitrification in the sludge layer in the secondary clarifier when conditions become anaerobic or anoxic. As the nitrogen gas accumulates, the sludge mass becomes buoyant and rises or floats to the surface. This effect is intensified at high water temperatures.

Filamentous Bulking is the result of either suppressing the normal wastewater treatment bacteria or promoting conditions favorable to filamentous microorganisms, such as fungi or actinomycetes which cannot be settled readily. The presence of filamentous microorganisms to the point where they interfere with settling is called bulking. This condition may be seen in the aeration tanks of activated sludge processes. The solids do not settle in the final settling tank and a homogeneous blanket of solids will pour out over the effluent weirs, especially during diurnal peak flow variations.

To avoid these problems *Membrane Bioreactors MBR* have been developed mainly by the producers of membranes. High concentrations of sludge in the activated sludge tank and the elimination of secondary settlement lead to very small space requirement for such plants. In the same time the investment costs and energy consumption is high.

Compared with traditional technologies the *Biofiltration Technology* has several advantages. The main advantages are cost advantages in terms of investment and operational costs. Long term investigations from 40 German Biofiltration plants over about 20 years of experiences shows significant lower energy consumption, lower sludge production and less operational problems compared with classical technology (Barjenbruch, 2010). In the same time biofiltration plants are more flexible for different loads and the treatment results of biofiltration plants are excellent.

Different aspects for the choice of waste water treatment technology are given in table 1. The table demonstrates that the BAF Biofiltration technology has several important advantages compared with classical technologies.

Figure 3 shows the space and energy requirement for different waste water treatment technologies. The space requirement for BAF is in the range between 0,05 and 0,15 m² per inhabitant combined with a relative low energy requirement between 13 and 25 KWh per inhabitant and year. The most space is required by activated sludge plants (AS), the highest energy consumption is required by MBR technologies caused by necessary high water pressure for the membranes.

Table 1: Aspects for different waste water treatment technologies (AS-Activated sludge, SBR-Sequencing Batch Reactor, MBR-Membrane Bioreactor, BAF-Biological Aerated Filtration)

Aspect	AS	SBR	MBR	BAF Biofilter
Investment costs	medium	low	**high**	low
Operational costs	medium	medium	**high**	low
Space requirement	**high**	medium	low	low
Energy consumption	medium	medium	**high**	low
Sensibility for water temperatures	**high**	**high**	medium	low
Risk for rising sludge / bulking	**high**	**high**	no	no
Know-how for plant operators	medium	**high**	**high**	low
Flexibility for different loads	medium	medium	medium	**high**
Treatment results	medium	medium	excellent	excellent

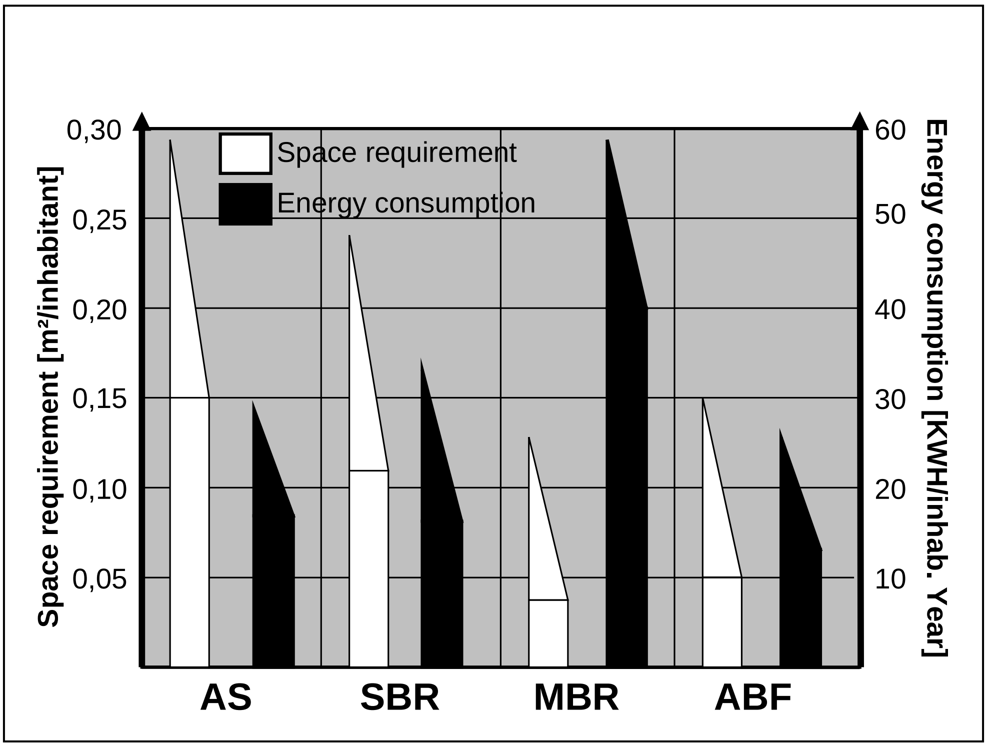

Figure 3: Space and energy requirement of different waste water technologies (AS-Activated sludge, SBR-Sequencing Batch Reactor, MBR-Membrane Bioreactor, BAF-Biological Aerated Filtration)

4. Presentation of technical sBAF plant and results

4.1 sBAF treatment plant of Guzet (France)

The wastewater treatment plant of Guzet-Neige is located in the French Ariège department (Pyrénées) at an altitude of about 1.200 m. The plant treats wastewater coming from a ski station including hotels and restaurants with a capacity up to 5.000 PE. The plant is characterized by important fluctuations in hydraulic and organic load caused by tourist activities, high concentrations at plant inlet as well as temporary low water temperatures (8°C).

The treatment plant has been realized as a full in-house solution because if the close tourist area (see figure 5). All equipment has been installed as prefabricated modular units (see figure 4). After mechanical pretreatment (rotary screen with compaction of screenings, lamellar primary sedimentation tank) the wastewater is equalized in a storage tank. It is then treated by 2 BAF filters for full biological treatment. Treated wastewater is directly discharged into the environment. The generated sludge is thickened in the clarifier up to 5% and stored in a sludge storage tank with a storage volume for 6 month.

Figure 4: Delivery and mounting of BAF filter and lamellar clarifier

Figure 5: sBAF waste water treatment plant

4.2 Results

The treatment results of the WWTP Guzet during one full year of operation are demonstrated in Figures 6 and 7. The results show that even with high concentrations and high variations in the inlet the outlet concentrations in terms of total N and BOD are more or less stable. The outlet concentration for BOD is normally in the range between 10 and 15 mg BOD/L. The Tot-N concentration at the outlet is usually < 20 mg N/l.

Figure 9 shows the COD outlet concentration of several municipal BAF plants as a function of COD volumetric load. Depending on the COD load, outlet concentrations in terms of COD in the range < 60 mg/l can be achieved. This low concentration can only be achieved by good filtering effect of the filter. The results shows that the result of BAF filters and the outlet concentration depend mainly on the volumetric load and less on the hydraulic load. This is the reason why BAF plants are adapted for waste water treatment plants with high variations in the hydraulic load.

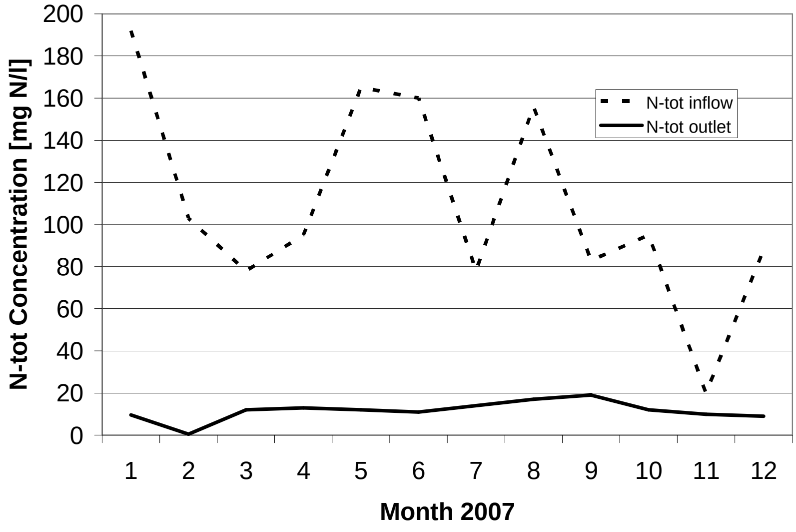

Figure 6: Tot-N in and outlet concentrations

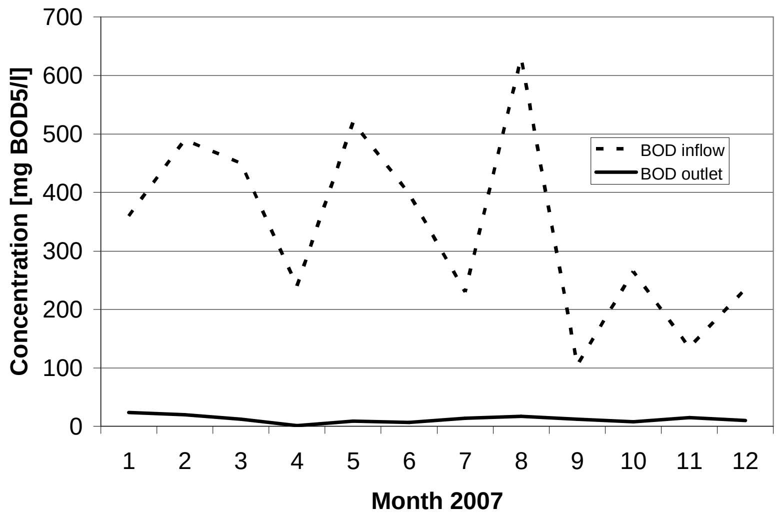

Figure 7: BOD in and outlet concentrations

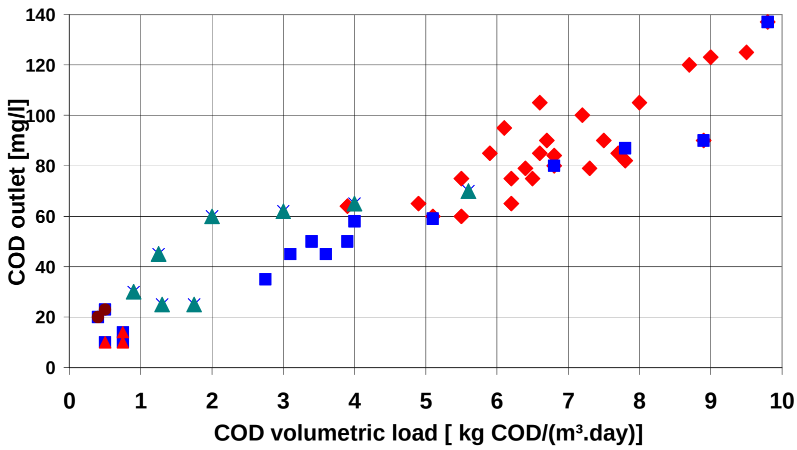

Figure 8: COD outlet concentration of several BAF plants as a function of COD volumetric load

5. Summary and discussion

SBAF technology is an interesting alternative to conventional Activated Sludge process, SBR or MBR technologies for small to medium sized wwtp. Long term experiences with about 500 plants in operation have shown that this system has the following advantages:

- High-grade wastewater purification with low outlet concentrations
- Complete automatic function
- Low energy consumption
- High process stability
- Marginal required space
- Modular concept
- BAF plant can easily be dismantled
- Suitable for fluctuations in sewage quantity
- Adapted to low and high waste water temperatures

Thus the biological upflow filter sBAF opens up further possibilities for a more economical and secure sewage plant operation even for smaller plants.

Literature

BARJENBRUCH M. (2010), "Benchmarking of Biofiltration plants. Operational experiences of 40 full scale Biofiltration plants in Germany", Technical University Berlin, Dept. of Urban Water Management

BOER A. (2009), "Romanian Policy and Strategies in the Water and Wastewater Sector", Romanian Business Digest, http://rbd.doingbusiness.ro/

BRINKE-SEIFERT S., OLDENBURG M., BEHRENDT J., SEKOULOV I. (1996): „Einfluss der Belüftung auf die Leistungsfähigkeit von Festbettreaktoren zur Nitrifikation" awt Abwassertechnik Heft 4/1996

RÜDIGER A. (1999): "Experiences with biofiltration in waste water treatment", Fourth BNAWQ Scientific and Practical Conference, Water Quality Technologies and Management in Bulgaria, 17.-19. Feb. 1999, Sofia, Bulgaria, Conference Preprints

SEKOULOV I., BRINKE-SEIFERT S. (1996): „Unter Wasser getauchte aerobe Festbettreaktoren – Beispiele, Pilot- und Betriebsergebnisse" ATV-Seminar : Einsatz von Biofilmreaktoren 25/26 November 1996, Essen - Germany

SEKOULOV I., BRINKE-SEIFERTH S., BEHRENDT J. (1997): „Biofilm-Technologie zur Reinigung kommunaler Abwässer: Mode oder Moderne ?", 26. Abwassertechnisches Seminar, Berichte aus Wassergüte- und BAFallwirtschaft Nr. 130, Technische Universität München

TANDOI V., JENKINS D., WANNER J. (2006): "Activated Sludge Separation Problems. Theory, Control Measures, Practical Experiences" IWA Publication, January 2006, Pages: 216, ISBN: 1900222841

Contact:

Dr. –Ing. Andreas Rüdiger
Water Expert
Albert-Lezius-Str.1
D-23562 Lübeck
Tel: +49 (0) 451 2037 782
Fax: +49 (0) 451 2037 783
E-Mail: info@abwasser-sachverstaendiger.de
Internet: www.water-expert.de