High efficient and flexible municipal waste water treatment using Biological Aerated Upflow Filtration BAF

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Summary

The Aerated Biological Upflow 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. The main advantages of using biofilters are the aptitude to adapt the treatment to a wide range of entering pollution loads, hydraulic variations in the inlet as well as to high temperatures of wastewater. The new generation of biofiltration is able to treat wastewater steadily, with high efficiency (>90%) and for lower costs compared to classical technologies.

1. Introduction

The GCC Countries represent today a population of about 40 Mio. inhabitants and are characterised by an important increase in the economic base, rapid improvement in the standard of living and high rates of development.

This development results in a substantial increase in water demands and water is becoming an increasingly scarce commodity. In this context high efficient waste water treatment and water reclamation technology became a very important factor for future developments.

Beside the high rate of population growth, the Golf States are characterized by special climatic and environmental conditions esp. high temperatures.

Bases on the described situation waste water treatment technologies in the Golf States should be high efficient to produce reusable water. In the same time the treatment plants should be modular and flexible for different hydraulic and organic loads and adapted for the special environmental conditions like high water temperatures.

The BAF technology meets the described claims and will be presented in this article. Technical details and practical results of the biological upflow filtration for the various functions are explained and commented in this report.

2. Aerated Biological upflow Filtration BAF

2.1 General aspects

The application of 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).

As regards the treatment of waste water, the first biofiltration plants were established in the 1980s. Presently, more than 500 plants are in operation in order to treat municipal and industrial waste water. The most important advantages of biological filtration are very good treatment results, low space requirements, modular and flexible concept as well as less sensibility for high waste water temperatures.

2.2 Presentation of BAF technology

An example of BAF-plant is portrayed in Figure 1. The rectangular reactor 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 from the bottom to the top (upflow). To maintain aerobic conditions and to allow aerobic bacterial growth on the material, the reactor is aerated also from the bottom to the top (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). 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. A secondary clarifier is not necessary.

Figure 1: Aerated Biological Upflow 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 4 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. 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 educed to around 1/4 compared to that required for activated sludge plants or SBR plants according to A 1 31 (Rüdiger, 1999).

Depending on the local conditions, this can mean that both the investment and annual costs for such a plant can be cut by 25 resp. 20% compared to the classical solution if a biological upflow filter is used. Thus the BAF technology has recently been approved by the Kuwait Ministry of Public Works and opens up further possibilities for a more economical and secures sewage plant operation.

3. BAF in relation to conventional technologies

One of the main engineering tasks in planning of waste water treatment plants is the best choice of the basic 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 smaller and medium sized treatment plants.

One of the main operational disadvantages for the activated sludge technology 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 nearly anaerobic. 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.

Different aspects for the basic choice of waste water treatment technology are given in table 1. The table demonstrates that the BAF technology has several advantages compared with other technologies and excellent treatment results in the same time.

Figure 2 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 m^2 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-Aerated Biological upflow Filtration)

Type of treatment	AS	SBR	MBR	BAF
Investment costs	medium	low	high	medium
Operational costs	medium	medium	high	low
Space requirement	high	medium	low	low
Energy consumption	medium	medium	high	medium
Sensibility for high water temperatures	high	high	medium	low
Problems with rising sludge and filamentous bulking	high	high	no	no
Education and know-how for plant operators	medium	high	high	low
Treatment results	medium	medium	excellent	excellent

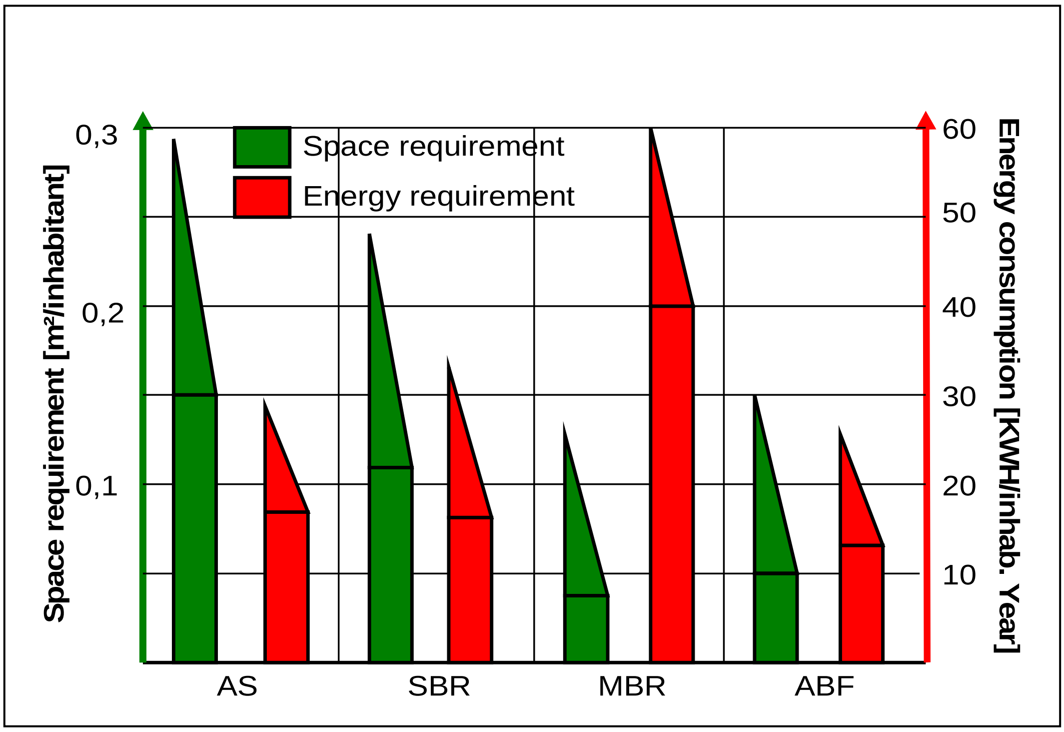

Figure 2: Space and energy requirement of different waste water technologies (AS-Activated sludge, SBR-Sequencing Batch Reactor, MBR-Membrane Bioreactor, BAF-Aerated Biological upflow Filtration)

4. Behaviour of biological waste water treatment at high water temperatures

A major design parameter for biological waste water treatment is the water temperature. The use of rooftop rain storage, cistern water, brackish water and the ambient conditions results in very warm sewage.

The general formula relating temperature to rate constants for biochemical reactions are as follows:

$$\mathbf{K_t = K_{20}\ 1.047^{(T-20)}}$$

where,

K_t = the rate constant for the sewage treatment reactions involved;

K_{20} = the rate constant for that same reaction at 20 degrees Celsius.

Using this equation, the rate constants can be calculated between 10 and 35 degrees Celsius. The result indicates a 3-fold increase in the rate coefficient. It is this high rate of biological reaction which results in unexpectedly high sulfide levels, very low dissolved oxygen concentrations and large biomass accumulation. All chemical moieties found in the sewage will arrive in the reduced state in much more microbiologically rich liquor.

The mentioned formula for the rate constant can be used up to 35℃. The main problem for water treatment for warmer waters in the range up to 45℃ can be considered in the denaturing process of enzymes. Especially the process of nitrification is a enzymatic conducted process. When enzymes are denaturated the process will be instable and will lead to high concentrations of nitrites with negative impact on the biological activity of the treatment plant.

Not only microbiological processes accelerated, but gas formation is also increased as temperature rises. Sludge rising in activated sludge plants and SBR systems is often a problem since sludge accumulates at a rapid rate and much gas is evolved in the material. In the same time it has to be taken into account that vertical water streams caused by temperature gradients can appear in the secondary clarifier. This will have a negative impact on sludge settlement and increase the concentration of suspended solids in the outlet.

For activated sludge plants where gravity return of settled activated sludge is common, the sludge will usually turn anaerobic.

The effect of increased temperature reduces the saturation concentration of oxygen in any process. In any system involving plug flow, initial oxygen demands will be very high. Flow to the plant will usually be anaerobic. The engineer should, therefore, anticipate 5-15 percent larger blower or bubbler air demands than required. Dissolved oxygen electrodes should be mandatory in hot climate wastewater treatment plant processes because both under and over-aeration will result in process disturbance.

BAF will not face the mentioned problems at high waste water temperatures because of attached biological growth which is more adapted to high water temperatures by specialized micro-organism. In the same time the system does not depend on the sludge settlement. Problems with rising sludge and filamentous bulking will not occur.

5. Presentation of technical BAF plants and results

In the following chapter two exemplary BAF plants of different sizes (5.000 and 700 m³ per day treatment capacity) will be presented including results of treatment.

5.1 BAF plant for 5.000 m³/day

A typical layout design of a wastewater treatment plant with a treatment capacity of about 5.000 m³ per day is presented in figure 3.

After mechanical pretreatment (coarse screening, aerated sand and grit chamber, primary sedimentation) the wastewater is lead into a hydraulic equalization tank. The full biological treatment is realized in 8 BAF units, with 4m of diameter each. Figure 4 shows a very compact layout. Each BAF filter unit (see figure 5) works independent and can be automatically stopped individually during times of low load.

The total surface area of the plant is about 75 m on 62 m. The specific space requirement is about 0,12 m²/PE.

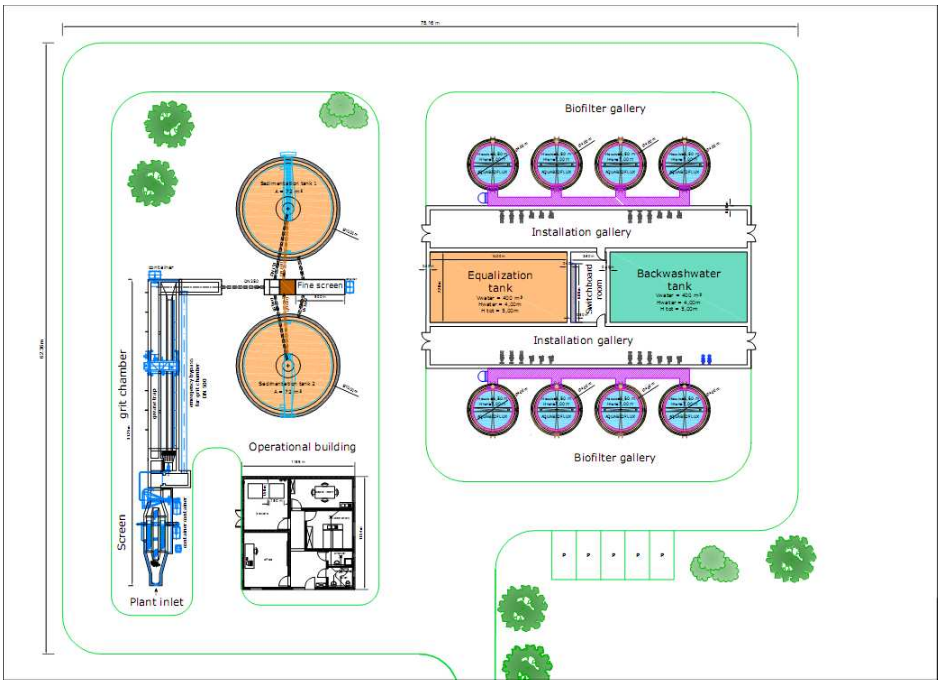

Figure 3: Layout of BAF plant 5.000 m³/day

Figure 4: BAF unit

5.2 BAF plant for 700 m³/day

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 as well as very low water temperatures (8℃).

The complete plant has been installed as prefabricated modular units (see figure 5). 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.

Figure 5: Delivery and mounting of BAF filter and lamellar clarifier

5.3 Results

Figure 6 and 7 shows the in- and outlet concentrations of a municipal BAF plant during a full year of operation. The results show that even with 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.

Figure 8 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.

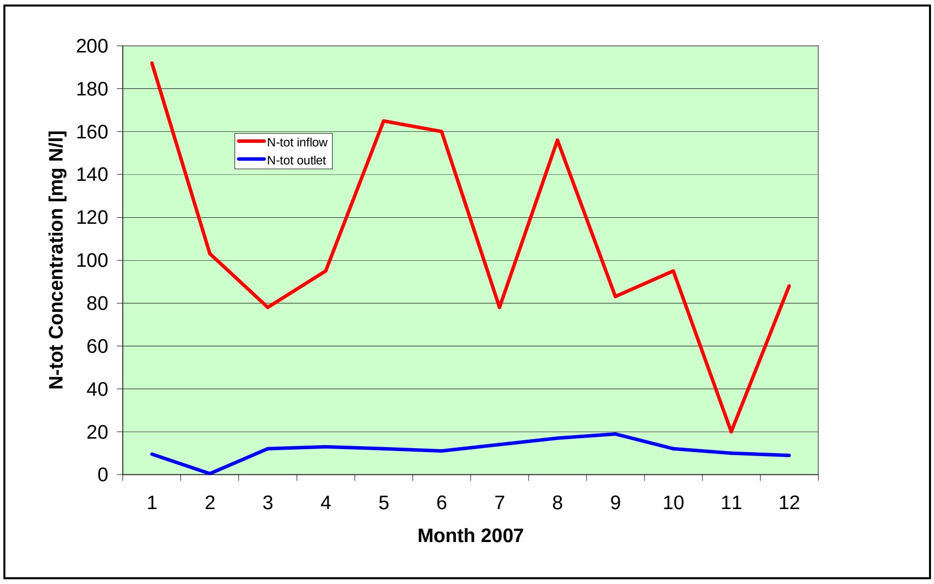

Figure 6: Tot-N in and outlet concentration of BAF plant

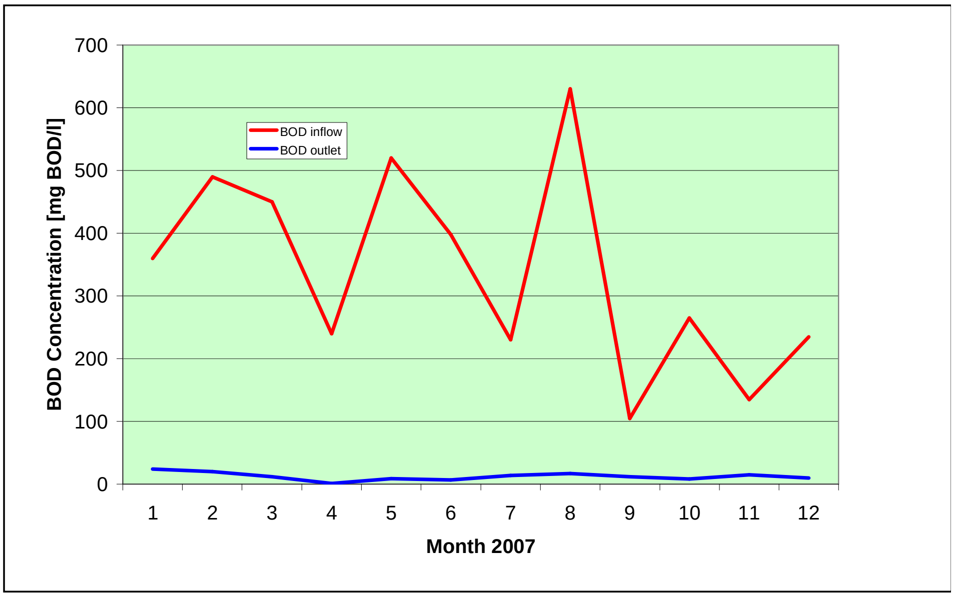

Figure 7: BOD in and outlet concentration of BAF plant

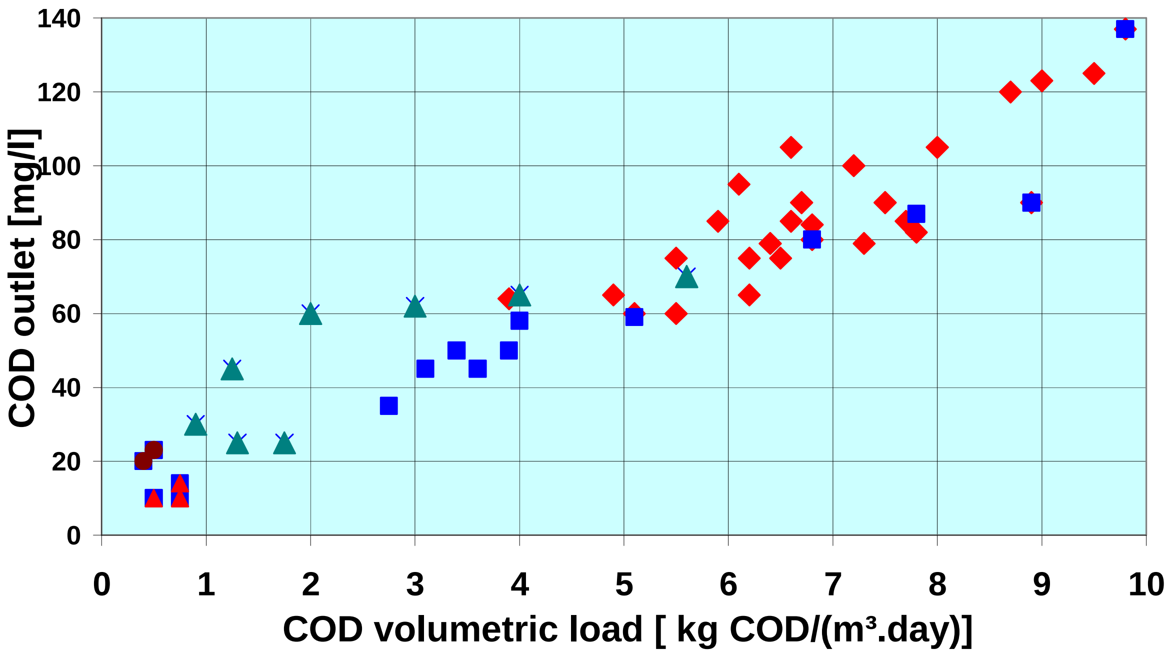

Figure 8: COD outlet concentration of several BAF plants as a function of COD volumetric load

6. Summary and discussion

BAF technology is an interesting alternative to conventional Activated Sludge process, SBR or MBR technologies. 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 high waste water temperatures

Thus the biological upflow filter opens up further possibilities for a more economical and secures sewage plant operation in the Golf states.

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