FS-BIO-005

TECHNOLOGY FACT SHEETS
FOR EFFLUENT TREATMENT PLANTS
OF TEXTILE INDUSTRY

SUBMERGED AERATED FILTER

SERIES: SECONDARY TREATMENTS

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INDITEX

SUBMERGED AERATED FILTER (FS-BIO-005)

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1. - INTRODUCTION

The principle of operation of an submerged aerated filter (SAF) is that a pre-treated or settled wastewater passes through a filter bed where a bacterial culture called biofilm degrades dissolved organic pollution. Also, a fraction of suspended solids and colloids are adsorbed by the biofilm and thus removed from the wastewater. Among others, submerged beds have the following advantageous features:

- stable operation
- simple operation (even used for detached houses)
- unlike suspended biomass processes it does not require sludge return or recirculation

The purpose of this sheet is to present the general criteria for the design of aerated submerged fixed beds.

2.- DESCRIPTION

Fixed beds are submerged biofilm reactors where the support or filling material is located below the water surface (submerged).
In fixed support beds, the filling material may be a structured module or bulk material, but the premise is that it has to be fixed without movement, as in a conventional bacterial bed. They can be called biofilm processes of Submerged aerated filter (SAF) (Tejero *et al.*, 1996). The biofilm excess is continuously detached by erosion so a final settling or filtration becomes necessary. However, bed backwash is not needed.

In most cases, it is considered as a good practice that treatment plants consist of more than one unit of aerated beds in series, so that the reaction unit is compartmented in several stages.

The rise of this process began in the 80s, its development was directed as an improvement to trickling filters performance. At present, they are used as:

- pretreatment, mainly from heavy loaded industrial wastewaters
- secondary treatment, with or without nitrification
- tertiary nitrification
- Simultaneous nitrification / denitrification

Hydraulically, they can function as mixed flow or plug flow reactors. They can operate as upflow (air co-current) or downflow (air countercurrent).

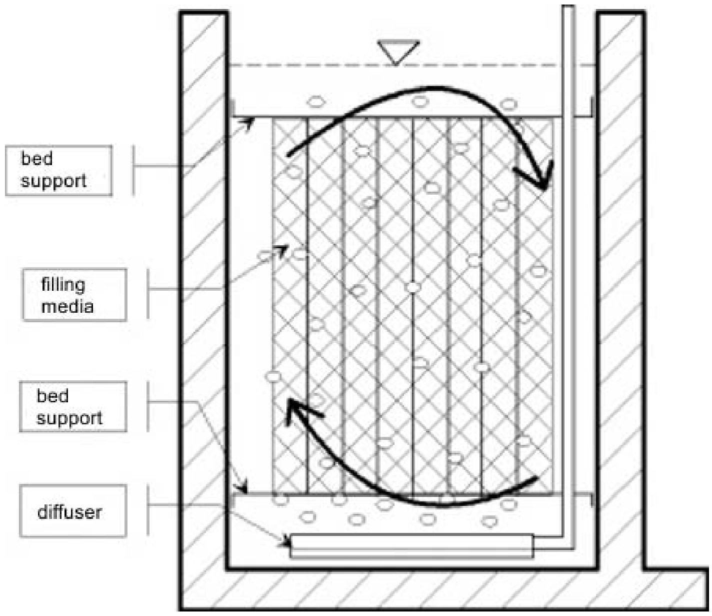

Figure 1. Scheme of a SAF process

2.1.- Biofilm support media characteristics:

As biofilm support, or bed filling, plastic materials are currently used with different configurations, both as bulk pieces randomly filling the reactor or as ordered modules conformed as a bed.

The main variables of the support media to consider are:

- Specific surface area: the support available area for the biofilm growth per unit bed volume (m^2/m^3).
- Porosity (void ratio): is the void fraction of the bed volume. It allows to estimate the effective or useful water circulation volume, and thus to estimate the hydraulic retention time (HRT). The higher the applied organic load, the bigger the porosity has to be; since the biofilm will become thicker.

The specific surface determines the amount of biofilm (m^2) which is able to grow per unit bed volume. However, a bed with a high surface area could involve an increased entrapment or retention of suspended solids, and the frictional losses are higher. Therefore more energy will be required to move water through the bed at a certain speed. Likewise, the probability of clogging is higher if the filler has a very high specific surface. A strong wash to unclog a support bed, entail the elimination of micro-protozoa and micro-metazoan (a cut in the food chain) and an increased production of sludge. For these reasons, the surface area of the support used for a submerged fixed bed installed for organic matter removal (secondary treatment) does not usually exceed 150 m^2/m^3, without occurrence of bed clogging.

Generally, submerged aerated filters are filled with corrugated plastic sheets, plastic tubes cuts, plastic meshes, etc., with surface areas of several tens to hundreds of m^2/m^3. A very commonly used media consists of a polyethylene mesh tube. The tubes are joined together in packs of 50-60 cm in edge length (Fig. Below). In these modules, the specific surface area ranges from 100 to 400 m^2/m^3, with a free flow area of 50 to 70%, porosity of 65 to 92% and the diameter of the mesh tubes ranges from 30-70 mm.

Figure 2.- Examples of modular fillers, with cubic shaped meshes

Another known filling is composed of modules or rope packages, is called ringlace (fig. Below).

Figure 3.- Rope fixed support Ringlace. Clean (left); colonized by biofilm (right)

Vendors sell support beds under the name SAF processes. When talking about SAF products almost always means submerged fixed beds. However, in some brands the fixed support does not imply a structured module but may be made of confined bulk pieces, "packaged" like those of the filling materials for a trickling filter (below).

Figure 4.- Right: Support media used in SAF processes used (average diameter: 12-15 cm). Left SAF unit filled with Pall-rings type bulk material (average diameter 9 cm).

Anyway, the bed filling is supported by a false bottom, based on a metal structure. Filling media height can reach 6 meters.

2.2.- Wastewater characteristics

Pollution parameters associated with the operation and design of the submerged aerated filters are:

- Suspended solids
- Nutrients
- Inhibitors
- pH and temperature, etc.

In order to avoid bed clogging a previous reduction of suspended solids is of great importance, particularly when a support media of high surface area is used. However, physical suspended solids removal causes an increase in the overall sludge production system, since a part of these solids constitute organic substrate when there is no pretreatment. Sludge production reduction can be performed through an anaerobic hydrolysis of the suspended solids eliminated in the physical pretreatment, where the liquid phase product feeds the submerged bed. In the case of small flows, combinations of Septic tank + submerged aerated filter or anaerobic filter + submerged aerated filter, will serve to reduce sludge production.

The biofilm systems generally have higher tolerance to the presence of inhibitory substances. They also have better resistance to abrupt changes in pH. Additionally, as the bed is immersed, it is less susceptible to fluctuations in ambient temperature.

2.3.- Aeration characteristics

2.3.1.- Aeration equipment

Coarse or fine bubble membrane diffusers are employed as aeration systems. The fine bubble diffusion achieves a more efficient oxygen transfer. However, coarse bubble systems are more frequent because they prevent clogging, and also due to the intense movement that they introduce beneath water, as a mammoth pump, which improves mass transfer into the biofilm (Schlegel and Koeser, 2007).

The air diffusion, besides supplying oxygen, induces an internal recirculation of water enabling intense contact between the biofilm and aerated wastewater, conducting to an oxygen transfer optimization and improving yields. Tubular membranes, commonly installed in one side of the tank, are also used.

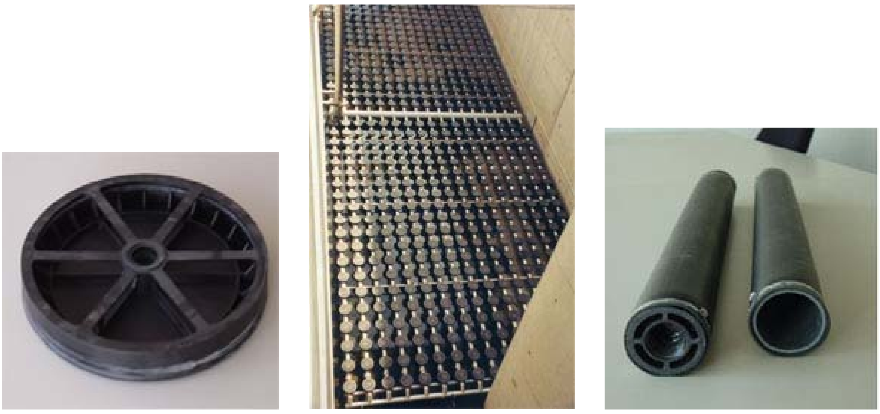

Figure 5.- Several types of diffusers: membrane discs (domes) and tubular membranes. In the middle frame, diffuser domes assembly, covering the bottom of a SAF unit, is shown (Reproduced from Naston Ltd., 2007, www.naston.co.uk).

Figure 6.- Left: BIO-BLOK filling media assembly, where coarse bubble aeration is observed. Right: diffuser assembly.

2.3.2.- Aeration modes

Aeration through diffuser systems take up space in the reactor and are installed directly below the filling media. By air diffusion the oxygen supply and also an internal recirculation allowing repeated contact with aerated biofilm wastewater are achieved.

Aeration can be of several types:

(1) Central aeration, in which air diffuses from the vertically placed shaft tube generating a radial recirculation flow (Scheme b);
(2) Uni-directional recirculation where the diffusers are installed along one of the reactor walls (Scheme a).
(3) Bidirectional recirculation in which the air diffusers are placed along the centerline of the reactor (Scheme c).
(4) It is also possible to introduce air bubbles directly through the bed. In one case the air is circulated into a bed zone and the recirculation flow is formed in the reactor (Scheme E), and in another, the air is introduced uniformly distributed throughout the reactor (Scheme d).

The oxygen transfer efficiency is higher in the aeration system through the bed than in the recirculation cases, but biofilm detachment will also be greater which conducts to a higher amount of sludge production.

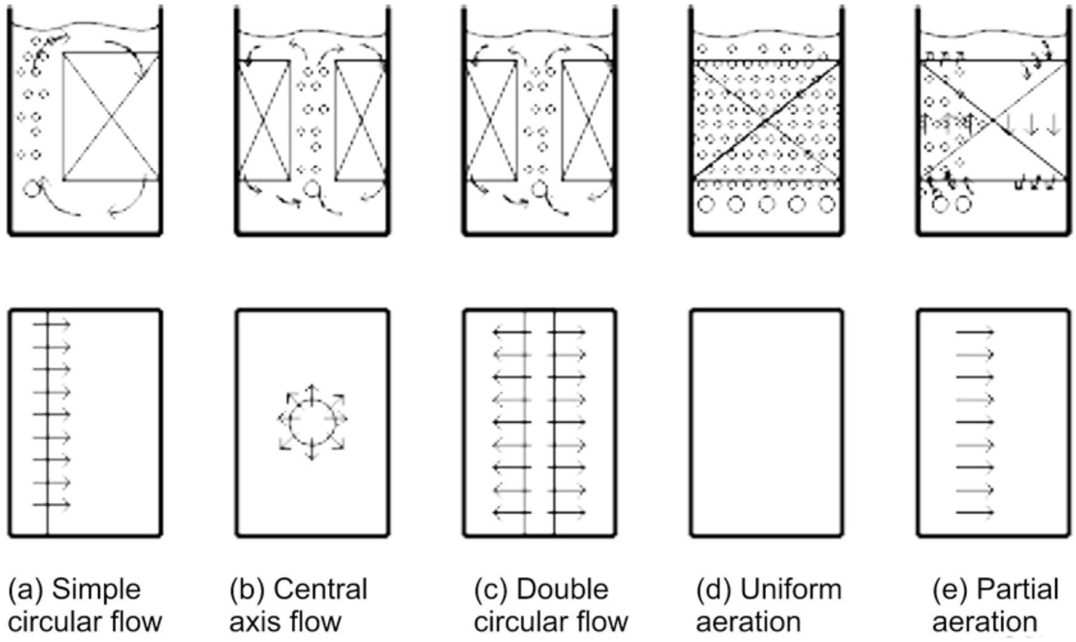

Figure 7.- Types of aeration to submerged aerated filters(Reproduced from Iwai and Kitao, 1994)

Mechanical aeration systems may also be used for oxygen supply and recirculation flows movements, but they are less employed than air injection.

3.- DESIGN

3.1.- Organic load

Organic load is the key parameter when sizing a secondary treatment. In biofilm processes design, the organic load can be expressed in terms of area or volume.

3.1.1.- Volumetric organic load

$$C_{V,COD} = \frac{Q_{ave}\ L_0}{V}$$

Where:

$C_{V,COD}$ = organic load applied per bed unit volume (kg COD/ m^3/ d)
Q_{ave} = Total average daily flow (m^3/d)
L_0= average influent COD concentration without recirculation (kg/m^3)
V = filling bed volume (m^3)

Domestic wastewater volumetric organic load typically ranges from 0.5 to 1.0 kg BOD_5/m^3/d. In terms of COD, it would be from 1.0 to 2.0 kg/m^3/d, considering that pre-treated domestic wastewater has a COD/BOD_5 ratio of 2.

The secondary treatment of an industrial wastewater from food processing (especially vegetables) volumetric organic load has reached values of 4.5 kg COD/m^3/d, employing a filling media with a surface area of 150 m^2/m^3 (Teichgräber and Schlegel, 2000).

In the case of a pretreatment, or a biological rough treatment, of the effluent from a carpet dyeing industry (av.COD=1,500 mg/L) volumetric organic load of 4.5 kg COD/m^3/d has also been used, obtaining a 60% efficacy in COD removal.

Another design example, in the Industrial wastewater from a tar processing industry treatment (average COD = 2,000 mg/L), used the SAF technology with organic load of 1.5 to 6.75 kg COD/m^3/d, obtaining a discharge between 80 and DQO 120 mg/L (Schlegel and Koeser, 2007).

3.1.2.- Surface organic load

$$B_{A,COD} = \frac{Q_{ave} \ L_0}{A}$$

Where:

$B_{A,COD,}$ = applied organic load per unit area of filling media contact (g COD/m^2/d)

A = contact surface of the filler material (m^2)

In the case of domestic wastewaters a common maximum value is 12 g BOD_5/m^2/d (24 g COD/m^2/d). In industrial wastewater, the range is 10 to 45 g COD/m^2/d.

3.2.- Filling media design criteria

Generally, the bed height is neither usually lower than 1.50 m nor more than 6.00 m. Support media for organic matter removal has typically a surface area from 100 to 150 m^2/m^3.

3.3.- Hydraulic retention time (HRT)

$$HRT = \frac{V}{Qave}$$

Where V is the effective liquid volume, that means, taking into account the porosity of the filling material.

The HRT depends on the concentration of the wastewater and can reach values of more than 1 day. In any case, the HRT should not be less than 90 minutes.

3.4.- Forced aeration

The oxygen amount requirement is related to the substrate oxidation needs and to the endogenous respiration of the biocenosis. However, it is not easy to determine the amount of biomass retained in the reactor as in the case of activated sludge, so that the oxygen peak demand is usually estimated by:

$$NO_x = NO_x^b \, F \, (L_0 - L_e) \, C_{p,F} \, C_{p,BOD}$$

Where:

NO_X= oxygen maximum need (kg/h)

NO_X^b = specific oxygen need (kg O_2/kg removed BOD) (= 0.8)

F = average treatment flow (m^3/h)

L_0, L_e = Influent and effluent BOD conc., respectively (mg/L)

$C_{p,Q}$ = peak flow coefficient (= F_{max}/Q)

$C_{p,BOD}$ = peak coefficient (if there is lack of data, a 1.50 value is adopted)

3.5.- Sludge production

The sludge production quantity is linked to the design organic load and/or to operation. The following table lists the specific production of sludge depending on the organic load:

Table 1.- Specific sludge production in submerged aerated filters

Organic load (kg BOD_5/m^3/d)	P_f^a (kg SS/kg BOD_5)
$\leq$ 0.5	0.50
> 0.5	0.75

A concentration of 1% in the waste sludge is considered.

3.6.- Sizing criteria summary

Table 2.- Characteristics of a SAF design for organic matter removal.

Parameter	Value
Surface area of the filling media, A_S, (m^2/m^3)	100 to 150
Organic load, B_A (g COD/m^2/d)	10 – 45
Filling height (m)	1.50 – 6.00

3.6.1.- Performance

The performance of a biological treatment has to do, among other factors, with the biodegradability degree of the wastewater. When the factor, or ratio, COD/BOD is less than or equal to 2.0 to 2.5 a yield of 90% in organic matter removal (COD or BOD) can be achieved, since the organic load is less than or equal to 10 g COD/m^2/d.

4.- SECONDARY CLARIFICATION

The optimal design of the settlers is essential to achieve the required performance to secondary treatment. If the solids are not retained by the clarifier, they will contribute to the BOD load of the effluent.

For simple sedimentation static circular or rectangular clarifiers can be used. Submerged aerated filters concentration at the reactor outlet can reach or exceed 400 mg/L, being applicable a zonal sedimentation theory.

4.1.- Design variables

- Surface hydraulic loading rate: based on the real flow rate through the unit, that is, which goes by the discharge weir (outflow).

$$HLR = \frac{Q}{A_{HLR}}$$

Where:
HLR = surface hydraulic loading rate (m/h)
Q = outflow (m^3/h)
A_{HLR} = horizontal surface of clarification (m^2)

- Hydraulic retention time:

$$HRT = \frac{V}{F}$$

Where:
HRT = hydraulic retention time (hours)
H = water depth side-wall (m)
V = useful volume for clarification (m^3)
$F = F_{max}$ (m^3/h)

- **Weir overflow rate:** corresponds to the effluent flow rate per linear meter of outlet weir.

$$WOR = \frac{F}{W_L}$$

Where:
WOR = Weir overflow rate (m^3/h/m)
W_L = weir length (m)
$F = F_{max}$ (m^3/h)

4.2.- Summary of design values

The following table summarizes the typical values for design parameters.

Table 3. - Design values for secondary sedimentation effluent from fluidized beds

Parameter	Value
HLR (m/h)	< 0.6 (F_{av}) < 1.5 (F_{max})
HRT (h)	> 2 (F_{max})
WOR (m^3/h/m)	< 10 (F_{max})
Sludge concentration (%)	≤ 1
H (m)	≥ 2.5

When the clarifier unit diameter is less than 5 meters, it is recommended to use truncated cone shaped clarifiers without scrapers, also called vertical flow clarifiers. In these decanters, the effective horizontal surface is set at the midpoint of the distance between the elevation of water entering the unit (ie, leaving the central baffle) and the elevation of the free water level (see figure below) .

In order to facilitate the real sludge sedimentation, the slope of the conical zone wall will respond to an inclination angle greater than or equal to 60º.

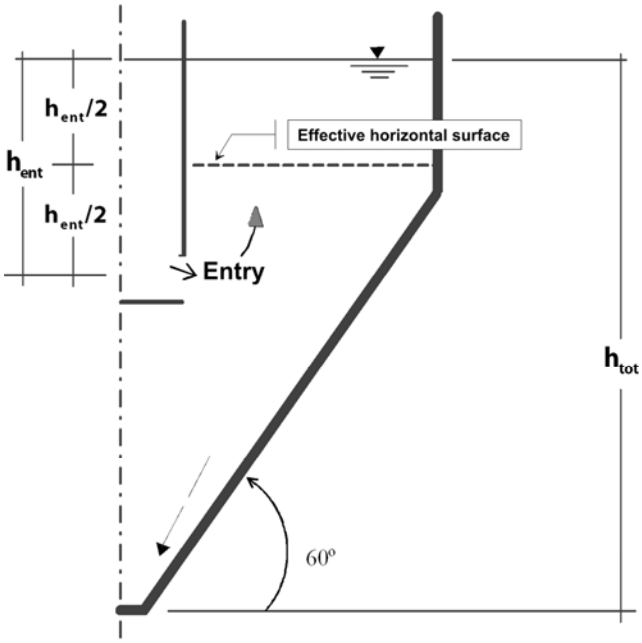

Figure 3.- Truncated cone shaped clarifier (Adapted from DWA 2000)

6.- SPECIFIC TECHNICAL CONDITIONS

Reactor

Bed height can reach 6 meters. The bed filling material is supported on a false bottom, based on a metal structure.

SAF reactors comprised by more than one aerated bed unit in series is considered as a good practice. It is about compartmentalize the process (Fig. below).

The SAF process is also used for removing total nitrogen through nitrification/denitrification. In this case it is necessary to incorporate one or more submerged non-aerated filters (anoxic), usually as pre-denitrification stages (Fig. below). However, anoxic or non-aerated bed, must be supplied by coarse bubble diffusers aeration systems, in order to wash off the excess biofilm and/or to release of gas nitrogen accumulation.

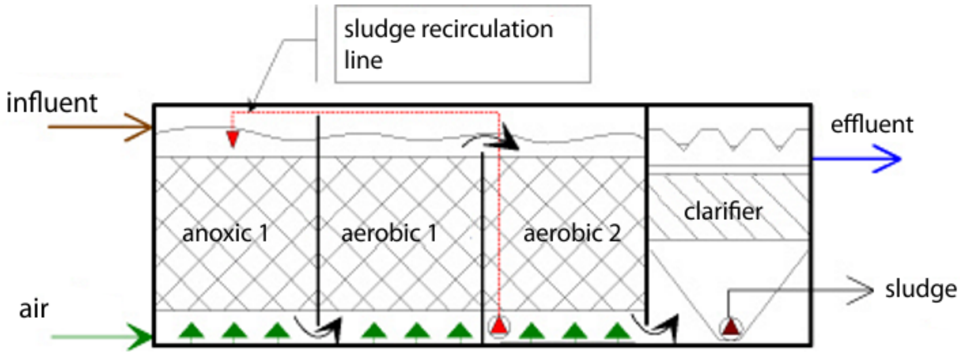

Figure 9.-Nitrification-denitrification system scheme based on 3-stage submerged aerated filters. The aeration applied on the anoxic bed is done for washing issues, as a purge for accumulated nitrogen, or even for process.

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It is possible that after a long period of operation, the effluent quality will deteriorate due to the release of excess biofilm. If necessary, the accumulation of biofilm must be removed by a washing unit, using air flow at high speed (20 m/h). Washing operations can last approximately 10 to 20 minutes. The aeration rate is referred to the area occupied by the bed. The German practice recommends a daily washing with the above listed criteria (20 m/h, 10 min, air flow) in order to prevent clogging, that is, it could be used as a preventive wash (DWA/ATV, 1997) .

Regarding the secondary clarifier design, the following shall apply:

- The decanted water collection weir; shall be of stainless steel 304L, attached to profiles assembled with the same materials.
- In any case, the secondary clarifier must have a baffle in order to avoid floatable materials discharge.
- Withdrawn foams and floating materials will never be returned to the plant head or to the pumping well.
- All bushings and stretches that will be effectively embedded in slabs or foundations are 304L stainless steel.
- The structural design shall consider the clarifier emptying.
- From the secondary clarifier treated water is transferred by gravity to the final discharge, which will have a manhole to cancel foam production, and a non-return valve so as to prevent any backflow.

7.- SPECIFICATIONS FOR THE TREATMENT OF WASTEWATER IN TEXTILE INDUSTRY

Submerged aerated filters were successfully applied as a pretreatment of industrial wastewater before entering a municipal WWTP. This pretreatment is advantageous in cases containing strong organic load wastewater or where organic matter has difficult or slow degradation. For heavily loaded industrial wastewater (IWW), it has been found that treated water recirculation is desirable (Schlegel and Teichgraeber, 2000).

There are still few experiences with SAF for real scale treatment of textile industry wastewater. In any case, the basic approach remains the same as for domestic wastewater treatment: the design must ensure "no bed clogging ". It is not just about getting a certain organic matter removal performance, but also that the bed is always in good operation condition.

In Germany, real scale processes have been designed and installed for the treatment of various types of industrial wastewater, eg food industry, pharmaceutical industry tar, and stained carpets (Schlegel and Teichgräber, 2000; Schlegel and Koeser, 2007).

In Northern Ireland, a real scale SAF demonstration has been undertaken for textile industry IWW. The project leader was the QUESTOR Centre (Centre for Research in Environmental Science and Technology) from Queen's University.

<u>**Case: carpet dyeing industry, textile industry**</u>

The aim of aerated submerged bed was to provide an organic load pretreatment to the effluent of this industry. The IWW is connected to the municipal WWTP Nottuln-Appelhülsen (Westphalia) which was designed for 27,000 e-h (on BOD basis), with the assumption that 4,000 e-h correspond to the textile industry. However, the increase in factory production multiplied industrial load by 4, and therefore the equivalent population reached 16,000 e-h (Schlegel and Teichgräber, 2000).

Thus, a submerged aerated filter of 1400 m^3 was designed and built for IWW pretreatment, using a 150 m^2/m^3 filling media that occupied a volume of 800 m^3. The textile wastewater presented a COD/BOD ratio = 3.8, which indicates that it is a waste of slow or difficult degradation. After a long adjustment period (three years), the SAF technology achieved the following results:

Table 4.- Average composition of influent and effluent of a submerged aerated filter for pretreatment of wastewater from a carpet dyeing industry (Source: Koeser and Schlegel, 2007)

Parameter	Unit	Influent	Effluent (startup)	Effluent after 3 years of operation
Inflow	m^3/d	800 a 1200		
Organic load	g $COD/m^2/d$	10 a 30		
COD	mg/L	1500 a 6000	1000 a 2000	800 a 1200

Then the effluent of the SAF is incorporated to the water treatment line of the municipal WWTP (Nottuln-Appelhülsen) based on activated sludge treatment, obtaining a final effluent with 5/32 /0.2/5 mg/L in BOD, COD, N-ammonium and N-nitrate respectively.

From gathered information of this study, at least 3 design criteria were extracted 1) the maximum design organic load (30 g $COD/m^2/d$, expressed in the table above), 2) the approximate HRT considering the overall volume (HRT=1400/1000 = 1.4 days) and 3) the reactor filling fraction (800/1400 = 0.57).

The report says nothing about color concentration in the treated water. In the industries focused on dyeing, color analysis should be a key treatment control parameter.

<u>Case: SAFTEX demonstration project</u>

In 2002, QUESTOR Centre, together with a group of companies (William Clark & Sons Ltd., STG Ltd., and Madden Associates), led a project to demonstrate the use and applicability of a submerged aerated filter for wastewater treatment (effluent) of the textile industry. The project was called SAFTEX ("SAF" Submerged Aerated Filter and "TEX" for textile).

The general characteristics of SAFTEX design at full scale were:

- Total volume: 60 m^3
- Treatment capacity: 240 kg BOD_5/d

The filling media type was similar to that called Pall-rings. The treatment system included a prior homogenization. The process was tested with high organic load: over 4 kg $BOD_5/m^3/d$ obtaining a biofilm development with an equivalent concentration of 10,000 mg/L MLSS.

Although performance results and/or treated water quality results have not been published, a project summary indicates that the optimization process allowed to achieve a treatment level enough to comply with discharge limit requirements (Groom, 2007).

Figure 10.- Biofilm grown on SAFTEX support media. This support is Pall-rings or similar type.

8.- PARAMETERS AND CONTROL STRATEGIES

Process control is based on the assessment and management on certain interrelated factors that favor the effective treatment of wastewater. These factors are:

- Required output water quality.
- Flow, concentration and characteristics of entry wastewater.
- Amount of required oxygen in order to meet oxygen demand of the inlet wastewater and maintaining an adequate level of oxygen to meet microorganisms' needs.
- Water distribution of the flow entering all identical processing units (two or more decanters or biological reactors).
- Pollutants transference from wastewater microorganisms (biofilm) and separation of suspended solids from the treated water.
- Effective waste control and extraction (solid, floating and supernatants) for final disposal without producing new pollutants.

8.1.- Aeration control

A point of great importance be controlled in biological reactors is the concentration of dissolved oxygen (DO). For this measurement a fixed or portable OD probe is used. In order to obtain an efficient oxidation of organic matter, an OD range between 1 and 2 ppm is considered as acceptable. In larger plants aeration is usually automated, so that, an aeration equipment dependent to the measuring OD probe will start or stop. In addition, if there are frequency inverters available in the aeration system, the supply air flow will be regulated.

In the case of small treatment plants, timed activation systems are commonly used, so it is recommendable to test the daily schedule where oxygen needs peaks are located, usually related to peak flows, and when oxygen needs are lower. It should not be forgotten that in small treatment plants, where there is usually no agitators, the aeration system serves as the mechanism to maintain the microorganisms suspended inside the water media, enabling a proper wastewater treatment. Thus, aeration should not have prolonged stop periods, so as to prevent particle settling in the reactor. Therefore, a maximum stop time has to be established (10-20 minutes).

8.2.- Settling and sludge waste control

In the case of more than one treatment line, it must be ensured that the treated water leaving the reactor or reactors is equally distributed among all secondary clarifiers.

Also, it is recommendable to prevent the settled sludge to be stored in the clarifier for a long time. This requires controlling the sludge purge pumping periods. In general, an hourly purge will be performed.

Although an installation is being properly operated, a certain amount of detached biofilm and/or low density flocs will float to the top of the decanter. A superficial baffle will avoid these floating materials to leave the clarifier with the treated effluent.

8.3.- Daily check in the reactor and in the clarifier

The tasks to be controlled and performed are:

- To observe the appearance of water in reactors and settlers.
- Adequate maintenance and lubrication in the aeration unit.
- To brush the outlet weirs of the clarifiers.
- Removal of grease and other floating materials such as pieces of rubber and plastic.

9.- OPERATION TROUBLESHOOTING

The main problem of exploitation that could present the submerged aerated filters is the bed clogging. As this problem can only be present in reactors with organic matter removal, design load is limited to 10 g COD/m^2/d and the surface area of the support material to 150 m^2/m^3.

Another problem could be the clogging and/or breakage of the air diffusers. To address this problem, the system design should facilitate access to the diffusers area, for example, leaving some separation between bed modules (an access chamber).

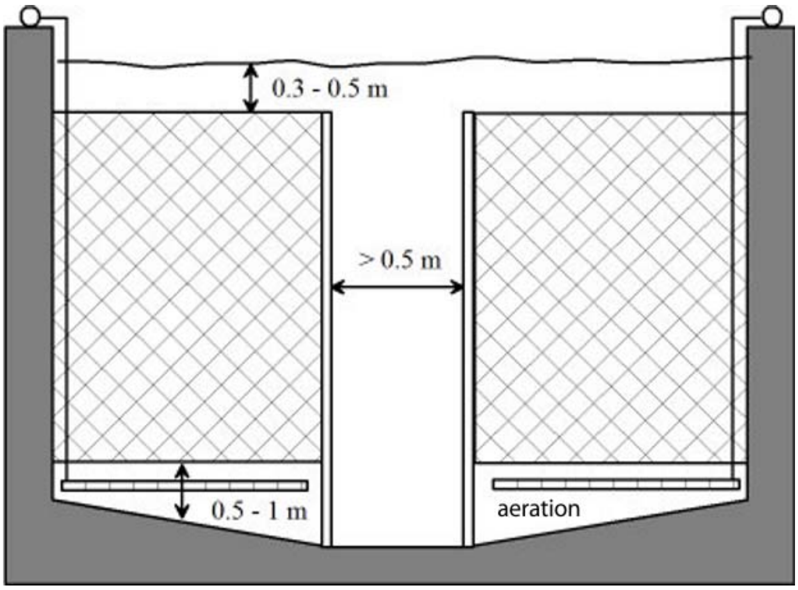

Figure 11.- Proposed configuration to design an easy access to the aeration zone for maintenance activities purpose.

Additionally, the combination of high content of residual detergent in the water with vigorous aeration, particularly with fine bubbles, can lead to an excessive foam production. The problem is that the detergent is dissolved organic matter, and thus a chemical process, such as coagulation and/or flocculation, as a pretreatment will not improve the wastewater quality. The solution in these cases can be complex, including: consumption of detergents optimization (source reduction), intermittent aeration inside the reactor, and use of anti-foaming.

Finally, an excessive concentration of oil and grease in wastewater (eg from raw wool washing process) is undesirable for all biological processes. The main negative impacts are: loss of efficiency in oxygen transfer and the possibility of accumulation in biomass. Any of these effects lead to a loss of treatment process performance. However, it is a problem easy to solve, since it can be overcome with a wastewater pretreatment which include a simple physical operation such as degreasing.

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ANNEX 1
AREA REQUIREMENTS ESTIMATION

1.- BIOLOGICAL REACTOR REQUIRED AREA

In the following table, the required surface for a biological submerged aerated filter is presented, provided for different sizes of textile industries in terms of average treatment flow. It is considered to be a homogenization tank for flow and concentration.

The general start hypotheses are:

- Homogenized BOD^5 concentration = 300 mg O_2/L
- Homogenized COD concentration = 1000 mg O_2/L

The main design criterion is the organic load, that shall not exceed:

- 0.5 kg $BOD_5/m^3/d$
- 10 g $COD/m^2/d$

The specific surface of the filling media will not be greater than 150 m^2/m^3.

The required area depends on the adopted bed height. In any case, this will not be less than 1.80 m and not more than 6.0 m.

Thus, the following results were obtained:

Tabla 1.- Area required estimation for submerged aerated filters at different treatment flows

		Filling height (m)	
		1.80	**6.00**
Flow rate	**Volume**	**Area**	**Area**
(m^3/d)	**(m^3)**	**(m^2)**	**(m^2)**
20	13.33	8	3
200	133.3	80	30
1000	666.65	400	150
2000	1333.3	800	300

2.- AREA RESUIRED FOR SECONDARY CLARIFICATION

In order to estimate the necessary settling area, the following design criteria are applied:

Hydraulic loading rate (Q_{ave}) = 0.6 m/h
Water mínimum depth = 3.00 m

The results are presented in the following table:

Table 2.- Estimation of required area for secondary clarification process applied for submerged aerated filters depending on the treatment flow

Flow rate	**Area**
(m^3/d)	(m^2)
20	1.4
200	14
1000	69
2000	139

Finally, the minimum area required for the "secondary treatment" is obtained by addition of the reactor and clarifier surface. The results are presented in the following table:

Table 3.- Minimum total required area estimation for secondary treatment (SAF reactor + settling)

	bed height (m)	
	1.8	6.0
Flow rate	**Total area**	**Total area**
(m^3/d)	(m^2)	(m^2)
20	10	5
200	89	37
1000	441	182
2000	880	362

ANNEX 2
GRAPHICAL DESCRIPTION OF PROCESS UNITS

Figure 1
SAF prefabricated systems. BIOCLERE® (www.naston.com, 22/07/02)

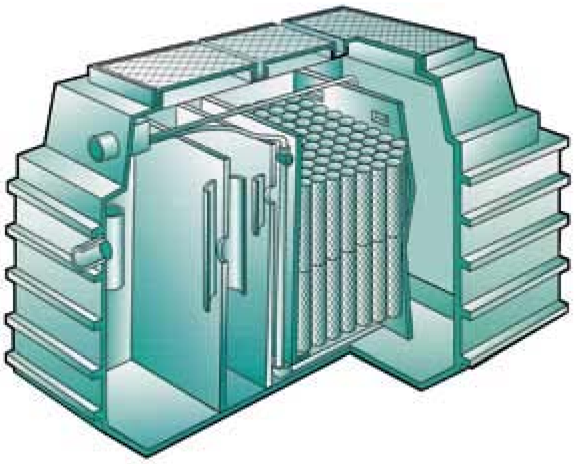

Figure 2
BAF process (Biological Aerated Filter). The primary treatment is septic dual-chamber type. The secondary sludge is returned to primary treatment (www.v63.net, 14/11/02).

Figure 3
SAF prefabricated systems (www.nottingham.ac.uk/~enzetc/guide/engsol, 08/11/02)

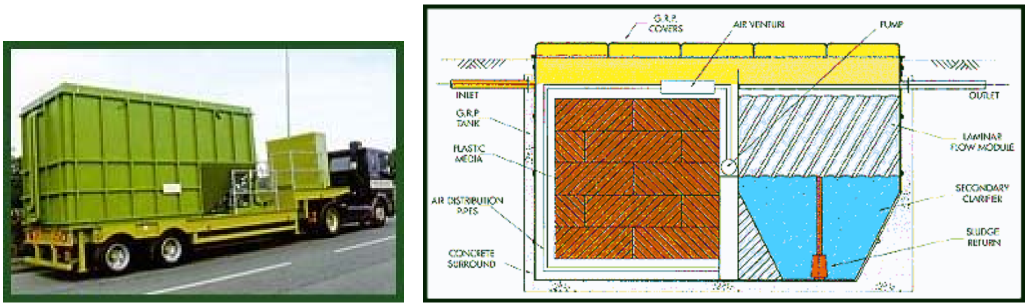

Figure 4
Compact steel plant. SAF process with separate settler. BIOCLERE® (www.naston.com, 22/07/02)

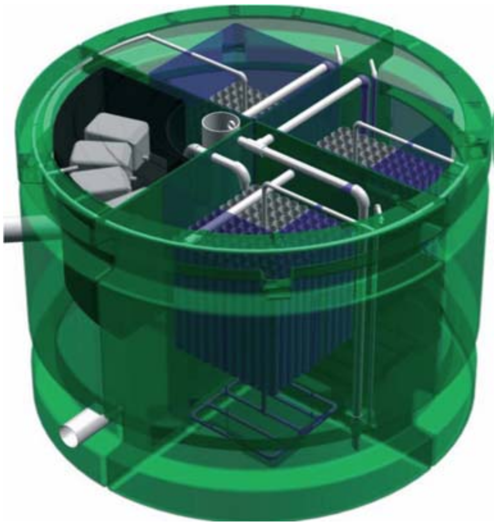

Figure 5
Compact system BioKube, to 30 e-h. It consists of three SAF chambers in series to oxidize BOD and ammonium (Biokube International, www.biokube.dk)

Figure 6
SAF process filled with loose pieces but not mobile. The specific surface area can be 120 or 210 m^2/m^3, backwashing is not required (Cooper-Smith, 2006)

Figure 7
Municipal WWTP for 1500 e-h. Two lines of SAF process (2 x 4 beds in series) (www.copa.co.uk)

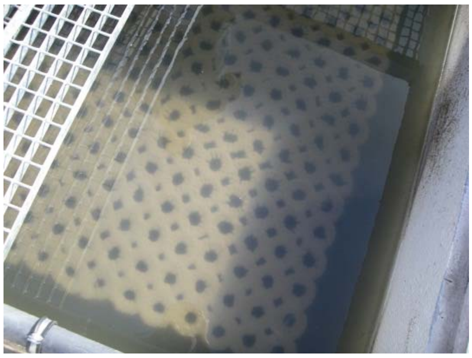

Figure 8
SAF process made of concrete. On the right, the filler material is observed colonized (coated) by the biofilm. (courtesy of INNDES, Ltd.)

Figure 9
General Installation of SAFTEX project (Sustainable Technologies Group (STG) Ltd.).