FS-BIO-006

TECHNOLOGY FACT SHEETS
FOR EFFLUENT TREATMENT PLANTS
OF TEXTILE INDUSTRY

AERATED BIOFILTERS

SERIES: SECONDARY TREATMENTS

TITLE	**AERATED BIOFILTERS (FS-BIO-006)**
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UNIVERSIDADE DA CORUÑA

INDITEX

AERATED BIOFILTERS (FS-BIO-006)

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1.- INTRODUCTION

An aerated biofilter consists of a bed of granular material acting simultaneously as a biofilm carrier and as a filter medium. Therefore, a biofilter has the dual purpose of biological treatment and suspended solids removal. The process can operate under aerobic or anoxic conditions, so that; biofilters can be used for organic oxidation alone, or in conjunction with nitrification, tertiary nitrification, nitrification and denitrification, and tertiary denitrification.

When the goal is to use this process as a secondary treatment, the raw wastewater has to be passed through screening, grit chamber and primary sedimentation processes.

In this sheet the application of biofilter technology for the removal of organic matter and nitrogen is described.

2.- DESCRIPTION

There are two types of beds to differentiate. Some are "pseudo-fixed" as a rapid sand filter because the filter material has high density (eg BIOCARBONE, BIOFOR, NITRAZUR, FLOPAC, Denite). Others are defined as "floating" because the filter material is much lighter than water and therefore the bed "floats" (eg Biostyr, FILTRAZUR, DENIPOR, biofilter).

The wastewater feed can be upwards (eg BIOFOR®, BIOSTYR®...) or downwards (eg BIOCARBONE®...).

The filter bed gets gradually clogged due to biofilm growth and retention of suspended solids. Solids retention inside the reactor avoids the need for a secondary clarifier.

The excessive biofilm is periodically removed from the biofilter by backwashing with air and water. Backwashing practice is then playing a similar role as the sludge purge into an activated sludge system.

Therefore, the reactor performs during operation:

- ✓ Suspended solids retention when wastewater passes through the filter bed.
- ✓ Biological transformation of organic matter by the biofilm.

This requires:

- ✓ High concentration of active biomass in the reactor (10 to 20 times higher than in an activated sludge process).
- ✓ Meeting the nutrients and energy requirements of the biomass
- ✓ Optimal management of wash cycles to purge excess biofilm regularly.

Therefore, aerated biofilters intensify the wastewater treatment process, managing to reduce space requirements. Volumetric organic load applied to these reactors can be five times higher than that commonly applied in the activated sludge, when the goal is organic matter removal.

2.1.- Main technical characteristics of the most common processes

BIOCARBONE®, BIOSTYR® and BIOFOR® are three of the biofilter typologies with more available technical information. This technical sheet is mainly centered on them.

2.1.1.- Support material

The supporting material must meet two objectives: the biomass fixation and solids retention. Material selection is a trade-off between two contradictory requirements: fine granulometry, suitable biomass fixation, and bigger granulometry, in order to limit the filter clogging rate.

The above technologies use different materials, as follows:

<u>BIOCARBONE® and BIOFOR®</u>

The general characteristics are:

- ✓ Size 2-6 mm, depending on the suspended solids load at water inlet.

- ✓ Relative density of about 1.5 g/cm^3 (higher densities involve increased energy expenditure during operation, especially when bed expansion is needed).
- ✓ Uniformity of granular material, so as to limit the risk of clogging due to fine particles.
- ✓ Good resistance to abrasion: the support material must retain its characteristics of shape and diameter.

The most used materials are of the silicates family. Pozzolana is also used. As an example, BIOCARBONE® employs a material called Biodamine (an expanded bituminous shale), and BIOFOR® uses Biolite (an expanded clay). Biofor® has a broad spectrum, since it can be applied to produce BOD removal, nitrification and denitrification. On the other hand Biocarbone is applied as organic oxidation and nitrification process.

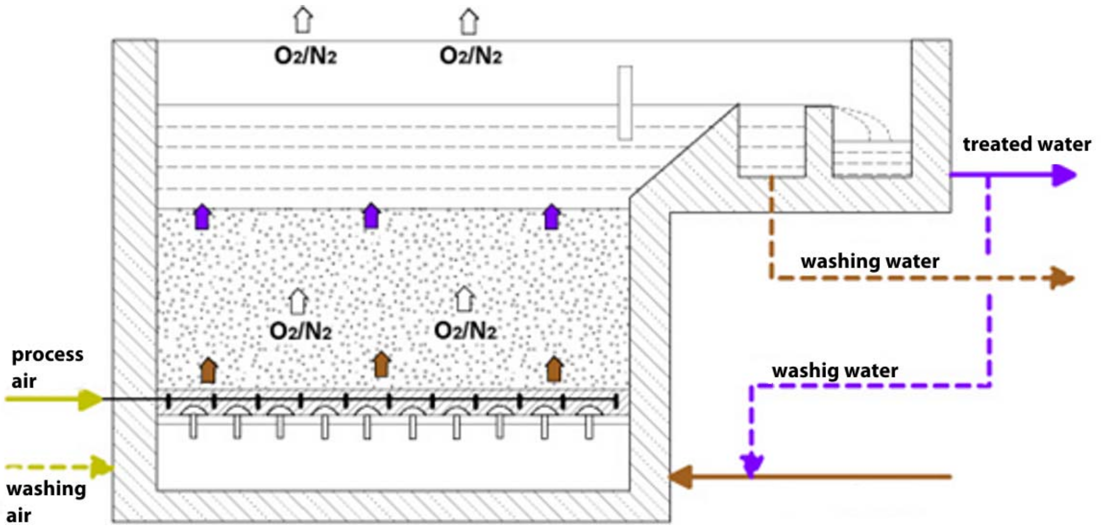


Figure 1.- Technology scheme BIOFOR® - Degrémont

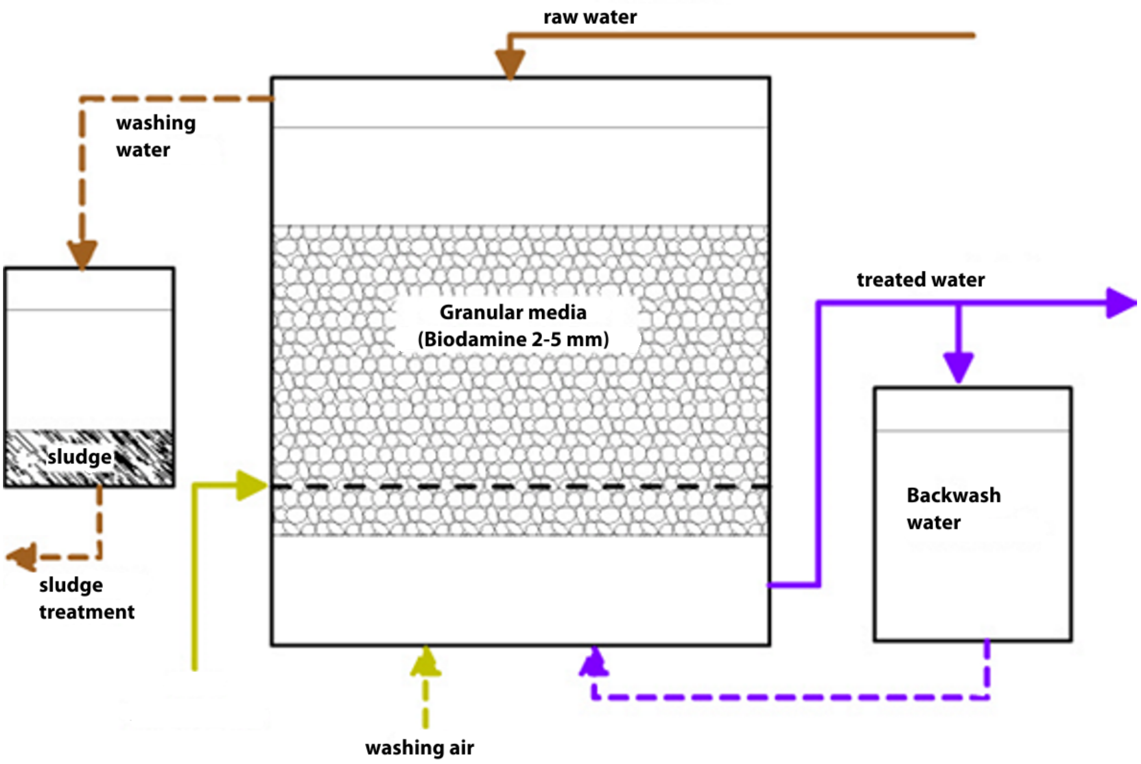


Figure 2.- Technology scheme BIOCARBONE® OTV

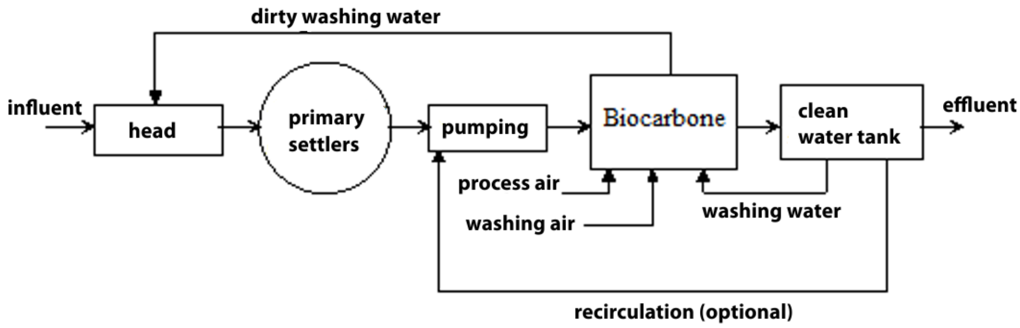


Figure 3.- Schematic configuration of a water line with secondary treatment technology based Biocarbone

<u>BIOSTYR®</u>

It uses polystyrene 2-6 mm "pearls" (Biostyrene™) which are much lighter than water. For this reason they float within the liquid, grouping in the top of reactor, where they are retained with nozzle deck that allows the treated water output as long as it keeps the support media.

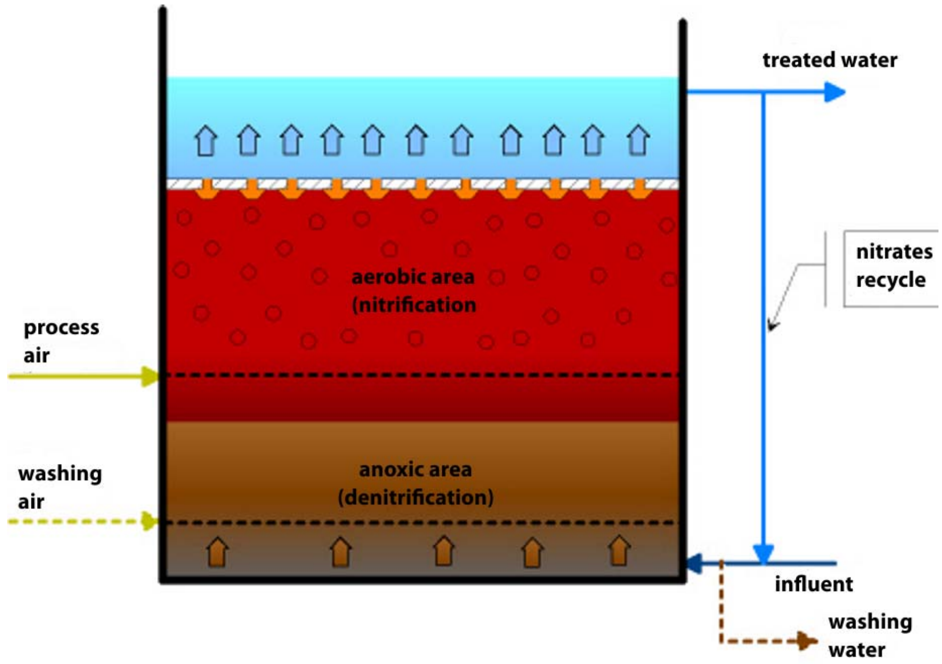


Figure 4.- Outline of nitrification-denitrification OTV BIOSTYR. Denitrification layer may not be necessary if what is sought is only the organic matter and/or ammonium oxidation.

2.1.2.- Fluid flow

It can be distinguished between:

- ✓ Downflow reactors (countercurrent) (BIOCARBONE)
- ✓ The upflow reactors (co-current) (BIOFOR Biostyr)

The co-current power facilitates the circulation and distribution of the fluid, while counter-current mode improves oxygen transfer.

By blown diffusers air feed share is ensured. The diffusers are located in the reactor bottom (BIOFOR®) or about 30 cm above the plate supporting the filter bed (BIOCARBONE®). Also, in BIOSTYR® diffusers, they are installed at a certain distance from the bottom.

Purification performance depends on the amount of oxygen supplied and efficiency of mass transfer. Transfer efficiency significantly depends on oxygen filtration height, being possible to achieve an efficiency of 20%.

2.1.3.- Backwashing

Inevitably biofilters are going to get clogged, so periodically washing will be needed. Washing must be effective in prolonging the operating cycles while retaining a fraction of the biomass needed for the process recovery after washing.

The cleaning cycle period (filter run) is 24-48 hours, with variation depending on the size of the filter material, the concentration of water and applied loads.

A biofilter wash lasts 20 to 40 minutes and generally comprises four stages:

- ✓ Unclogging the bed by blowing large volumes of air.
- ✓ Detachment of part of the biofilm using a mixed flow of water and air.
- ✓ Properly washing
- ✓ Rinse and disposal of washing sludge (excess sludge)

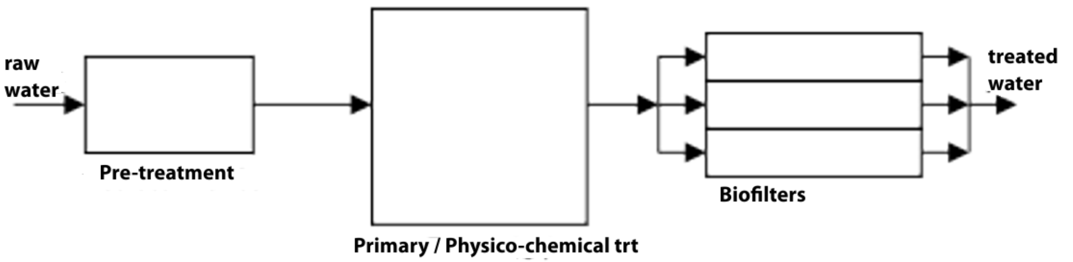
Part of the secondary treated effluent water is normally stored in a tank and used as washing water. Washing air is blown onto the filters deck of filters entering the reactor.

The optimized operation of the biofiltration unit requires good match between the applied load and the frequency of the washings. The influent concentration of COD, BOD, SS; is a limiting factor about the duration of a water feed cycle. For BIOFOR maximum allowable concentrations are on the order of 200 mg/L SS and 400 mg/L COD.

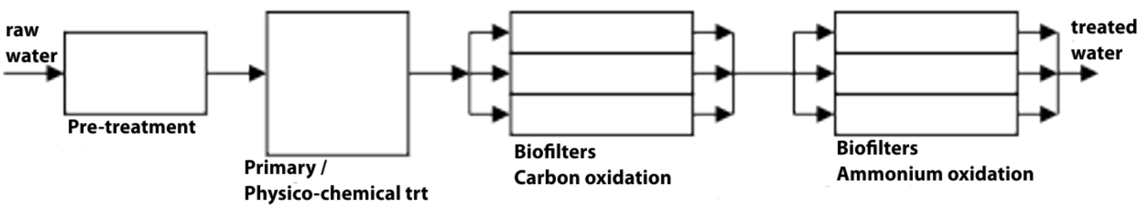
2.1.4.- Line treatment configuration examples

Then possible treatment lines are shown incorporating biofilters:

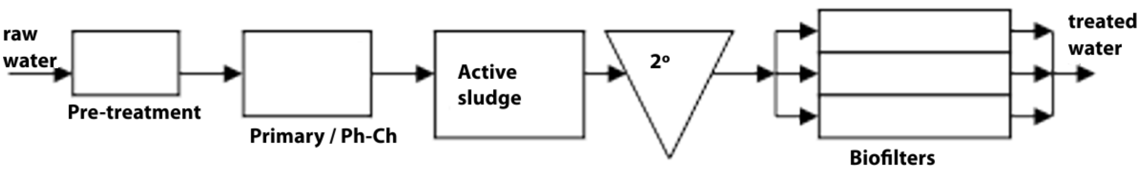
Case 1: Organic matter elimination (secondary treatment)



Case 2: Carbon and ammonium oxidation



Case 3: Complementary treatment (nitrification or denitrification, tertiary)



2.2.- Summary of characteristics of the common commercial biofilters

Table 1. Characteristics of supporting media flow biofilters and Trademarks

Process	Type of flow	Support	Specific gravity	Size (mm)	As[(a)] (m^2/m^3)
Biobead®	Upflow	Polyethylene	0.95		
Biocarbone®	Downflow	Mudstone expanded	1.6	2 - 6	
Biofor®	Upflow	Expanded clay	1.5 – 1.6	2.7, 3.5 and 4.5	1400 - 1600
Biostyr®	Upflow	Polystyrene	0.04 – 0.05	3.3 - 5	1000
Biolest®	Upflow	Pozzolana	1.2		

3.- GENERAL DESIGN CRITERIA

As seen previously, this technology market is characterized by responding to a particular brand. Thus, design parameter values shall meet "manufacturer" criteria.

Regarding workloads two biofilters operation parameters should be observed: hydraulic loading rate and volumetric pollutant load. A third general parameter is the hydraulic retention time. However, a fundamental operation for the process success is the backwashing, so this is where the main manufacturer's indications are specified.

- The surface hydraulic loading rate, CH, (also known as filtration rate) is expressed in m/h ($m^3/h/m^2$):

$$HLR = \frac{F}{A_f}$$

Where:
F = volumetric flow rate (m^3/h)
A_f = filtration area (m^2)

- The **volumetric load**, L_V, expressed in kg of pollutant/m^3/d, is calculated by:

$$L_V = \frac{FC_i}{V}$$

Where:
C_i = influent concentration of the pollutant i (kg/m^3)
V = reaction volume (m^3)

- Hydraulic retention time, HRT, defined as:

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

Where:
V_w = volume occupied by water (m^3)
The volume occupied by the water can be 50% of the fill volume of the reactor. The rest is occupied by the filter material and the air. Retention times are typically between 30 and 40 minutes.

3.1.- Typical values of the parameters for secondary treatment

Organic load varies widely in biofilters designed for secondary treatment, in a range from1.5 to 6 kg $BOD_5/m^3/d$. Meanwhile, the average hydraulic load is usually in a range of 4-7 m/h, and 10 to 20 m/h at peak flow. Typical values for these design parameters are presented in the following table. The organic load is usually the limiting design parameter criterion, considering that there is normally a previous primary sedimentation treatment.

Table 2. Typical loads of biofilters for secondary treatment

Type of biofilter	Pollutant load ($kg/m^3/d$)	Hydraulic load (m/h)	Performance (%)
Upflow, submerged or floating support [(a)]	BOD: 1.5 to 6 SS: 0.8 to 3.5	3 to 16	BOD: 65-90 SS: 65-90
Upflow or downflow, submerged support [(b)]	COD: 4 to 11 SS: 1.1 a 5.4	Average: 1.6 to 2.9 Maximum: 4.5 to 7.1	BOD: 69 COD: 65 (59 to 74) SS: 71 (63 to 84)

[(a)] WEF (2010).
[(b)] Pujol (1991). Evaluation of full-scale plants with Biofor® and Biocarbone® (support: expanded clay)

The filling height is variable, and depends on technologies or trademarks. However, a typical value is 3 to 4 meters. Also, the maximum unitary surface depends on the brand, being a common value up to 144 m^2.

Sludge production is usually 0.7 to 1 kg SS/kg BOD_5 (WEF 2010) (or 0.4 kg SS/kg COD, according to Pujol 1991).

Biofilters typically have high power consumption (aeration and washings). By way of example, the average power installed capacity is 200 W/m^3 in upstream filters (BIOFOR) and 350 W/m^3 in downstream ones (BIOCARBONE). The specific energy consumption has a range of 1 to 2 kWh/kg COD removed. Biofilters expenditure accounts for a 65% of the total energy consumption of the plant (Pujol, 1991).

3.1.1.- Backwashing

In general, a daily washing is required when the process is applied as secondary treatment. This has to do with the SS load, the degree of hydrolysis occurring within the bed, the biomass production and the solids holding capacity of the bed. The sludge volume that may accumulate between each washing process is 2.5 - 4 kg SS/m^3, this depends on the support medium, filtration rate and water temperature (Degremont, 2007).

In biofilters washing a slight expansion of the bed is sought, and the cleaning is possible thanks to the joint participation of air + water. The air produces much friction between particles and solids detachment.

The phase sequence in the washing process comprises: Unclogging, air + water cleaning, rinse and sludge disposal. The following table presents a comparison between backwashing operations values.

Table 3. Summary of washing needs of biofilters (Adapted from WEF 2010)

Type of biofilter	Water rate (m/h)	Air rate (m/h)	Total duration (min)	Total volume of wash water per filter
Upflow,submerged support	20	97	50	12 m^3/m^2
Upflow, floating support	55	12	16	2.5 m^3/m^3
Downflow,submerged support	15	90	20 to 25	3.75 to 5 m^3/m^2

In any case, each brand has its peculiarities in backwashing operations. Normally, an interaction between engineering design and the supplier will be required to determine the particular washing process characteristics.

Case study at real scale (Pujol, 1991)

In two WWTP (with Biofor and Biocarbone systems) washing characteristics were:

Rate	Biofor	Biocarbone
Air (m/h)		
* Unclogging	70	47
* Cleaning	70	47
***Water* (m/h)**		
* Cleaning	40	20
* Rinsing	40	13

The washing periods were 20 to 40 minutes. The main difference consist on the fact that, in the upstream filters (Biofor) washing is performed once, while in the downstream (Biocarbone) several successive mini-washings (about 5) are being performed.

The solids concentration in the washing water (excess sludge) was 500 to 1,000 mg/L, with a pH of 7.5. The first 15 washing minutes (3 mini-washings in Biocarbone) are the most effective ones.

3.1.2.- Performance estimation as a secondary treatment

Pujol (1991) made a detailed assessment about several biofilters systems operation at real-scale (Biocarbone and Biofor), studying the response of the steady-state units against load variations. A linear relationship between effluent COD and volumetric organic load was observed at a steady-state:

$$COD_{ef} = 10.6\ Cv + 11.1\ (R^2 = 0.94)$$

According to the expression above, an effluent COD concentration below 100 mg/L can be obtained with influent loads up to 8 kg COD/m^3/d. It was also noted that, at steady state, the average COD removal efficiency is stable and independent of the volume load, being approximately 70%.

The increase in COD is mainly due to the soluble COD fraction, since the ratio between effluent SS and volumetric organic load has the following expression:

$$SSef = 2.5\ Cv + 3.2\ (R^2 = 0.82)$$

For a load of 8 kg COD/m^3/d, the effluent SS are around 24 mg/L. These solids represent approximately 36 mg/L of COD, so that the remaining 64 mg/L are due to the soluble organic matter fraction flowing through the effluent. A 35 mg/L of SS is achieved for loads up to 12 kg COD/m^3/d.

3.2.- Typical operating values for nitrification and denitrification

When nitrification comes together with organic oxidation, low temperature organic load needs to be limited to a maximum of 2.5 kg BOD_5/m^3/d (Rogalla et al., 1990, cited in WEF 2010). This limitation can achieve TKN removal rate of 0.4 kg/m^3/d.

Table 4. Typical loads for biofilters nitrification

Type of biofilter	Volumetric load kg/m³/d	Hydraulic load m/h	Removal %
Upflow, submerged or floating support, secondary	BOD < 1.5 to 3 SS < 1.0 to 1.6 NH_3-N<0.4(0.6 to 10 ºC) <1.0 to 1.6 (20 ºC)	3 to 12	BOD: 70-90 SS: 65-85 NH_3-N: 65-75
Upflow, submerged or floating support, tertiary	BOD < 1 to 2 SS < 1.0 to 1.6 NH_3-N<0.5 to 1.0 (10 ºC) <1.0 to 1.6 (20 ºC)	3 to 20	BOD: 40 – 75 SS: 40-75 NH_3-N: 75-95
Upflow, floating support, tertiary	NH_3-N : 1.5		
Upflow, submerged support, tertiary	NH_3-N : 1.2		

Denitrification can precede the nitrification stage (pre-denitrification), or it can be installed downstream to other processes (post-denitrification or tertiary denitrification).

The following tables show load values for denitrification.

Table 5. Nitrate load for pre-denitrification in biofilters (WEF 2010)

Type of biofilter	Volumetric load kg/m³/d	Hydraulic load m/h	Removal %
Upflow, submerged support, separate stages (pre-denitrification + nitrification)	NO_3-N: 1 to 1.2	10 to 30	NO_3-N: 75-85
Upflow, floating support, combined stage anoxic/aerobic	NO_3-N: 1 to 1.2	12 to 21.5	NO_3-N: 70 no extra carbon; 85% carbon surcharge.

Table 6.- Nitrate load for post-denitrification in biofilters (WEF 2010)

Type of biofilter	Volumetric load $kg/m^3/d$	Hydraulic load m/h	Removal %
Downflow, submerged support	NO_3-N: 0.3 to 3.2	4.8 to 8.4 (average) 12 to 18 (peak)	NO_3-N: 75-95
Upflow, submerged support	NO_3-N: 0.8 to 5.0	10 to 35	NO_3-N: 75-95
Upflow, submerged support	NO_3-N: 2.0		
Upflow, floating support	NO_3-N: 1.2 to 1.5		

3.2.1.- Specific review on BIOSTYR® characteristics

Biostyr® is used for the secondary or tertiary wastewater treatment. The air is injected from the base of the bed (secondary treatment) or above the bottom of the reactor (tertiary treatment). As the filter material is very light (Biostyrene™), a plate with nozzles of filtration is installed on the top of the bed to retain or prevent filter media to escape with treated water.

Excess solids are purged by washing with water and air for biofilm excess detachment.

Typical bed height is 3-4 meters. For removal of nitrogen, air injection is done at 1 m above the bottom of the bed. The anoxic / aerobic volume ratio is 1/3, but could be up to 2/3. The nitrified water is recirculated at a rate of 200%. The production of odors is low or nonexistent. However, aerosols production is possible. In the table below reported design criteria for Biostyr process is presented.

Table 7. Typical load values for Biostyr® design (WEF 1998)

Process	Design load
Nitrification	1.1 - 1.3 kg TKN/m^3/d
Nitrification - Denitrification	1.1-1.2 kg TKN/m^3 aerated/d 1.2 kg NO_3-N/m^3 anoxic/d
Tertiary denitrificación	3 kg NO_3-N/m^3 filter/d

In the following table, reported yields on the operation of Biostyr aerobic nitrification are presented:

Table 8. Biostyr® tertiary nitrification process yields (WEF, 2000)

Parameter	*Load ($kg/m^3/d$)*	*Removal ($kg/m^3/d$)*	*Performance (%)*
TKN	2.12	1.83	86
Ammonium-N	1.87	1.67	89

Biostyr® effluent quality has also been reported as follows (WEF, 1998):

Table 9. Biostyr® effluent quality (WEF, 2000)

Process	Parameter	Effluent
Nitrification	TKN	< 5 – 10 mg/L
Nitrification - Denitrification	TN	< 5 – 20 mg/L
Tertiary denitrification	NO_3-N	< 2 mg/L

Sludge production in the case of tertiary treatment is relatively low, so that washings are less frequent, taking place every 36 to 48 hours.

4.- SPECIFIC TECHNICAL CONDITIONS

4.1.- Pretreatment and primary treatment

Depending on the type of biofilter, a fine screening unit should be implemented at various points in the ETP. In any case, it is essential to incorporate a fine screen upstream the inlet of a biofilter used with bottom feed nozzles. A simple manual screen with a max. opening of 2.5 mm may be enough to protect this biofilter typology if previously, in the pretreatment, there is already a fine screen unit. However, it requires this additional screening for several reasons: raw wastewater pretreatment may be poor, additional flows without screening enter the unit (septic tanks sludge, imported sludge, etc.), there can be trees around, or open channels without coverage.

For a small plant, high load primary treatment (lamellar settler) is often used. For example, a primary treatment improved with chemicals addition, lamellar settlers or ballasted flocculation (sand) and settling.

4.2.- Backwash handling facilities

The facilities and equipment for biofilter backwashing include effluent clearwell, washing water pumps, washing air blowers, washing water collection tank, and required automation (valves, instruments, controls, etc.) for washing start-up and operating.

In multi-stage biofilters systems with different equipment dimensions, units, etc., washing sizing will be done for the critical situation, that is, for the largest unit, in order to avoid undesirable in washing equipment dispersion characteristics. Final effluent water, pumped from an outlet channel or via a final clearwell, will be used as washing water flow. The effect of washing water return must be taken into account in the system design. In tanks having intermediate effluent for washing (between biofilters units), a downstream flow to the following units and /or disinfection system must be ensured.

When washing water collection tanks are large, a stirring system should be installed to prevent sludge sedimentation. Washing sludge may contain part of the filter medium accumulated over time. Washing water return pumps should be designed to avoid medium particles flowing into the intake pipes and pumps.

Both washing flows and sludge purges are returned to the treatment plant head where solids are removed inside the primary sedimentation. This generally improves the primary clarifiers performance because biosolids adsorb some BOD, and also improve the rheological properties of primary sludge and simplifying its handling and pumping (WEF 2010).

Alternatively, the return flow can be treated with a specific separation system. This can be of particular interest in large installations (more than 100,000 m^3/d), where the existing primary sedimentation tanks may have limitations for sludge handling or if biofilters systems comprise several stages in series. Different technological options could be used as ballasted flocculation, FAD system, etc.

4.3.- Aeration

Process air distribution systems in biofilters include:

- Sumple pipes with sparge holes drilled at intervals positioned in media or near the floor of the filter. Coarse bubble aeration through sparging pipes is used widely.

- Diffusers placed on a pipe grid at the floor of the reactor to obtain even air distribution at low airflow rates, rather than to produce smaller bubbles for improved oxygen transfer efficiency.

- Injection of air under the plenum, frequently used to scour filters during backwash, also can be used during filtration. It is based on the use of nozzles for air diffusion, similar to those used for filters washing in water purification systems. This system provides efficient aeration, but requires periodic chemical cleaning to prevent biological growth from blocking the air holes, causing poor air distribution and increasing energy costs.

Several factors complicate the control aeration process:

- In general, biofilters operate primarily as plug flow systems, so that the dissolved oxygen (DO) at the top of the reactor does not represent the dissolved oxygen concentration within the media.
- Oxygen transfer not only takes place from dissolved oxygen in water, but also occurs by direct interfacial transfer from gas to biofilm, which cannot be accounted for with a dissolved oxygen probe.
- In systems aerated by a coarse-bubble air grid, the minimum flow to provide effective distribution of air can exceed process requirements.

Blower selection is important for efficient plant operation. AS solids accumulate in the media, filter headloss increases, which can affect the air flow. When several biofilters cells receive air from a common main, backwashed cells will have the lowest headloss and will take more air flow. This balancing issue can be mitigated by providing individual blowers for each biofilter cell. For larger plants a centralized blower station with a common air main, air pipes feeding each cell are fitted with a mass flow meter (measuring velocity, pressure, and temperature). The meter is used to control a modulating valve, which balances air flow to the cells (WEF, 2010).

4.4.- Supplemental Carbon Feed facilities

In tertiary denitrification systems, and in some pre-denitrification, an external carbon substrate (electron donor) must be dosed to the biofilter. Methanol typically has been used for this purpose. Increasingly, alternative carbon sources are being considered including ethanol, acetic acid, and sugar solutions.
Carbon dosage control is important for tertiary denitrification systems. Overfeeding wastes chemical and could increase the BOD of effluent. Underfeeding the carbon source reduces the amount of nitrate removed, and the plant may not achieve the desired effluent nitrate or total nitrogen concentration. Several alternatives exist for control carbon external carbon dosing:

Dose control is crucial to carbon tertiary denitrification. If there is excess dose impairs effluent quality in terms of BOD, and otherwise deficit dose may limit nitrate and total nitrogen are infringed. Thus there are several alternatives for controlling the dosage of external carbon:

- Manual control: for manual control of chemical dosing, all pumping rate adjustments and sampling are performed manually.

- Flow-paced control: Based on influent nitrate concentration and the required level of nitrate removal, the average carbon dose requirement is determined. The control system is then set to modulate pumping rate with fluctuations in wastewater flow. Typically flow-pacing applies only to dry weather operation.

- Control based in flow and influent nitrate measurements. Because the carbon dose is based on both wastewater flow and concentration, it is feasible to operate in this mode during wet and dry weather.

- Feed-forward and feedback with effluent concentration control: This represents the most complex level of chemical feed control. Systems with this capability are currently offered as proprietary packages by several denitrification filters system suppliers. Some are based on flow and nitrate only, while others incorporate nitrite and dissolved oxygen readings.

5.- SPECIFICATIONS FOR THE TREATMENT OF WASTEWATER OF TEXTILE INDUSTRY

Chang et al. (2002) utilized a pilot scale biofilter filled with natural zeolite during 5 months textile wastewater treatment of an industry in Seoul - Korea. The average composition of the real wastewater was (in mg/L, except color): COD = 2150; BOD_5 = 1630; SS = 63; TN = 72; and Color = 740 (in units of color). The industry processes natural (wool and cotton) and synthetic fibers (polyester, nylon, polyacrylic and polyamide). The biofilter reactor had an area of 1.05 m^2 and a medium volume of 3.15 m^3 (H = 3.0 m). The void volume was 2 m^3. The specific gravity of the zeolite was 1.42 and the treatment flow was 12 m^3/d. The biofilter was able to remove up to 99% of the BOD; 92% of COD; SS 74% and 92% of TN under a hydraulic head of 1.83 m/h. While color reduction was 78% due to the high adsorption capacity of the zeolite.

Liu et al. (2008) employed an aerated biofilter with two medium materials for the tertiary treatment of a secondary effluent of a textile sector ETP. The bed had a volume of 15.7 liters, 50% of which was ceramsite and the other half of GAC. The ceramsite is a non-metallic mineral with high porosity and high surface area. The layer of ceramsite filters and degrades the organic matter lighten the load to the GAC layer which adsorbs non-degradable organic matter, and ensures quality water for reuse. The ceramsite characteristics were: diameter = 2-3 mm; Density = 740-790 kg/m^3; specific surface area 3.99 m^2/g. While the GAC: diameter = 1-2 mm; Density = 460-510 kg/m^3 and surface area = 960 m^2/g. The hydraulic load is controlled in a range from 0.13 to 0.78 m/h. The average composition of secondary effluent (tributary of the biofilter bi-layer) was (in mg/L): COD = 57; BOD = 12; N-$NH4^+$= 8; NT = 14; SS=33 and pH = 7.2. Under stationary conditions the system achieved a good effluent quality with COD, N-NH_4^+ and TN of 31, 2 and 8 mg/L, respectively.

Xujie et al. (2009) used a line in series, consisting on ozonation and aerated biofilter, in order to bleach and reduce the COD of a wastewater containing reactive red X-3B, an azoic dye. Bleaching was complete after a contact time of 120 minutes at a concentration of O_3 to 34 mg/L, and in this period the BOD_5/COD ratio increased from 0.102 to 0.406, that is, the water became more biodegradable, what helped to make the biological process more effective for COD reduction. Under the following conditions: gas/liquid = 3; hydraulic load = 4.8 m/d; T = 20-25 ° C mass ratio ozone/dye = 4.5 and pH = 11; the concentration of COD and color achieved was 40 mg/L and 20 Pt-Co, respectively, which represented a yield of 97% in color bleaching and 90% in COD removal.

Amaral et al. (2014) evaluated biological system composed by a UASB reactor and aerated biofilter (BF), in series, designed to remove color and COD of a real wastewater from a laundry industry in Pernambuco (Brazil). The cylindrical reactors had a diameter of 40 cm; the UASB with a height of 2 m and a volume of 250 liters while the biofilter had a height of 1.50 m and a capacity of 187 L, and was filled with pseudo-spherical expanded clay (diameter = 2 cm; density = 0.389 g/m^3, and water absorption of 10.8%). The system was operated for 335 days with HRT of 14 h (8 h UASB + 6 h BF) at 21 h (12 + 9 hours). The best color reduction efficiencies were 30% in the USAB and 96% on the overall system. The best performance of the biofilter was attributed to adsorption phenomenon. Moreover, the authors concluded that high concentrations of sulphates (<300 mg/L) in wastewater deteriorated the color reduction performance. The highest efficiency of the system in COD reduction was 71%. In the UASB sulfur precipitation (98%) and some metals occurred. However, precipitated sulfur was further oxidized in the aerated biofilter. The system also showed a reduction in toxicity of the wastewater, which was measured by Daphnia magna inhibition assays.

6.- CONTROL PARAMETERS AND STRATEGIES

Aerated biofilters perform on a single unit both secondary treatment processes: oxidation of organic matter and retention or removal of suspended solids (water clarification). Thus, in the effluent of a biofilter the level of organic matter (BOD, COD) and suspended solids (SS, turbidity) must be controlled

The use of SAC-254, for organic matter control, and suspended solids or turbidity continuous probes facilitates the process control.

Additionally, it is important to control the concentration of dissolved oxygen (DO) performed with a DO probe. In larger plants aeration is usually automated, so that, depending on the DO concentration, aeration equipment will start or stop. In addition, aeration flow will be regulated it there are frequency inverters available.

7.- OPERATION PROBLEMS

One problem could be the breakage or the clogging of the air blowers. To address this problem, the system design should facilitate access to diffusers area.

Additionally, the combination of high content of residual detergents in wastewater with vigorous aeration, particularly with fine bubbles, can lead to excessive foam production. The solution in these cases can be complex, comprising: detergents consumption optimization (source reduction), intermittent reactor aeration, and anti-foaming use.

Finally, an excessive concentration of oil and grease in wastewater (eg from washing process or wool) 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 process performance. However, it is an easy problem, then, can be resolved with a pretreatment of wastewater that includes a simple physical operation such as degreasing.

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ANNEX 1
AREA REQUIREMENTS ESTIMATION

SURFACE FOR BIOLOGICAL REACTOR REQUIRED

Surface demand is presented for a aerated biofilter at different sizes of the textile industry expressed in terms of the average flow of treatment. Is considered to be an homogenization tank for flows and concentrations.

The general hypotheses are:

- Homogenized BOD5 concentration = 300 mg / L
- COD concentration homogenized = 1000 mg / L

The main design criteria are the organic load and speed of filtration:

- 5 kg $BOD_5/m^3/d$
- 10 kg COD/ m^3/d
- 3 m/h

The area required depends on the adopted medium height. In any case, It won't be less than 3.0 meters.

Thus, the following results were obtained:

Tabla 1.- Estimation of surface needs to submerged aerated biofilter according to the flow to be treated

Flow rate	Volume	Area
(m^3/d)	**(m^3)**	**(m^2)**
200	20	7
1000	100	33
2000	200	66
4000	400	132

ANNEX 2
GRAPHIC DESCRIPTION OF UNITS OF PROCESS

Figure 1.- The biofilter system technology Biostyr

Figure 2.- Aerated biofilter system of technology Biofor

Figure 3.- Aerated biofilter system of technology Biocarbone

Figure 4.- Aerated biofilter system prefabricated metal structure for flow rates up 1000 m^3/d.