

FS-BIO-003

**TECHNOLOGY FACT SHEETS
FOR EFFLUENT TREATMENT PLANTS
OF TEXTILE INDUSTRY**

TRICKLING FILTERS

SERIES: SECONDARY TREATMENTS

TITLE	TRICKLING FILTERS (FS-BIO-003)
Last update	September 2015
Last revised	

TRICKLING FILTERS (FS-BIO-003)

Date	September 2015		
Authors	Alfredo Jácome Burgos Joaquín Suárez López Pablo Ures Rodríguez		
Revised by			
Last update	Date	Done by:	Update main topics

INDEX

1.- INTRODUCTION

1.1.- *Trickling filter classifications*

1.1.1.- Standard Rate Filter

1.1.2.- Intermediate Rate Filter

1.1.3.- High Rate Filter

1.1.4.- Roughing Filter

1.1.5.- Super High Rate Filter

2.- DESCRIPTION

2.1.- *Filling media characteristics*

2.2.- *Wastewater distribution characteristics*

2.3.- *Aeration characteristics*

3.- DESIGN

3.1.- *Design parameters*

3.2.- *Sizing criteria*

3.2.1.- Low and medium load beds

3.2.2.- Roughing filter

3.3.- *Application intensity (SK)*

3.4.- *Forced aeration*

3.5.- *Sludge production*

4.- SECONDARY CLARIFIER

4.1.- *Design variables*

4.2.- *Summary of design values*

5.- SPECIFIC TECHNICAL CONDITIONS

6.- SPECIFICATIONS IN THE TREATMENT OF WASTEWATER OF TEXTILE INDUSTRY

7.- PARAMETERS AND CONTROL STRATEGIES

8.- OPERATION TROUBLESHOOTING

BIBLIOGRAPHY

ANNEX 1 REQUIRED SURFACE ESTIMATION

ANNEX 2 GRAPHIC DESCRIPTION OF PROCESSING UNITS

1. - INTRODUCTION

The operating principle of a trickling filter consists on a pre-treated or settled wastewater, flowing through a filtering bed where a bacterial culture, called biofilm, has been adhered and developed. The wastewater, thus irrigated on the filter material (or filling material), contacts with the biomass achieving pollution degradation. The suspended and colloidal materials present in wastewater get agglomerated and are adsorbed by the biofilm. Among others, biological filters have the following advantageous features:

- Stable operation
- They tend to be simple to operate
- Unlike suspended biomass processes, they do not require sludge return or recirculation
- The energy demand is lower than in suspended biomass processes.

The purpose of this document is to present the criteria for the design of trickling filters for organic matter removal.

1.1.- *Trickling filter classifications*

Trickling filters are classified on the basis of their hydraulic and organic loads. They may be classified as low or standard, intermediate, high, or super high rate (Table 1).

1.1.1.- Standard Rate Filter

Standard rate trickling filters are normally designed for hydraulic ratings of 1.1 to 4.3 m³/m²/d and organic loadings of 0.08 to 0.41 kg BOD/m³/d. These filters are normally 1.8 to 2.4 m deep and rectangular or circular in shape. They are usually dosed intermittently by dosing tanks with automatic siphons or by periodic pumping. The interval between dosing will vary with the rate of wastewater flow, but should be short enough to prevent filter growths from becoming dry. Some recirculation may become necessary to achieve this. During normal operation, a thick growth develops in the filter until a temperature change or the flow through the filter causes a large portion to slough off. This sloughing usually occurs in the spring or fall and is known as "unloading." The sloughed material is a stable, easily settled, humus-like material, frequently containing many worms and filter fly larvae.

1.1.2.- Intermediate Rate Filter

Intermediate rate filters are normally designed to treat hydraulic loadings of 4 to 10 m³/m²/d and organic loadings of 0.24 to 0.48 kg BOD/m³/d including recirculation. In the past, there have been some cases in which the organic loading in the intermediate range stimulated considerable biological filter growth and the hydraulic loading was not sufficient to eliminate clogging of the trickling filter medium. Other plants operating in this range have had few operational problems. In some cases, intermediate rate filters are actually under loaded high rate filters.

1.1.3.- High Rate Filter

High rate filters are normally designed for substantially higher loadings than are standard rate units. A filter receiving a BOD loading from 0.4 to 4.8 kg BOD/m³/d. These filters are usually 0.9 to 2.4 m deep and circular in shape. They are designed to receive wastewater continuously. The high rate of application is achieved by recirculating wastewater that has already passed through the filter, and the heavy flow of wastewater over the filter medium produces continuous rather than periodic sloughing of the filter growths. Because the solids are not retained in the high rate filter as long as they are in the standard rate unit, they are less stable and continue to exert BOD after they leave the filter. The solids are also much lighter and more difficult to settle than those sloughed from a standard rate filter.

1.1.4.- Roughing Filter

Roughing filters are basically high rate filters treating an organic load of more than 1.6 kg BOD/m³/d. (It is not uncommon to load roughing filters at rates in excess of 3.2 kg BOD/m³/d). In many cases, these filters are used to pre-treat the waste before its feeding to an activated sludge plant. Most roughing filters designed today use synthetic media.

1.1.5.- Super High Rate Filter

The major differences between super and high rate filters are greater hydraulic loadings and a much greater filter depth. Some super high rate filters are designed to handle hydraulic loads of more than 162.3 m³/m²/d. Most of these filters are in the form of packed towers with depths to 12 m. It is the use of synthetic media

that permits the high loading rates and greater filter depth. The microbial layer that grows on the trickling filter media is the most important part of a trickling filter. The organisms in the microbial layer feed on the pollutants in the sewage and convert them to solids that will settle out of the sewage. As the microbial layer grows, a portion detaches or sloughs from the trickling filter media.

Table 1.- Classical typologies of trickling filters (Adapted from WEF 2000; WEF - ASCE 1992, 1998)

Parameter	Low or standard rate	Intermediate rate	High rate	Super high rate	Roughing
Media	Stone	Stone	Stone	Plastic	Stone/plastic
Organic loading* (kg DBO ₅ /m ³ /d)	0.08 - 0.4	0.24 - 0.4	0.4 - 4.8	To 4.8	>1.6 to 3.2
Hydraulic loading (m ³ /m ² /h)	0.04 - 0.15	0.15 - 0.4	0.4 - 1.5	0.6 - 3.6*	2.5 - 7.0*
Recirculation (%)	Minimum or it does not exist	Usually	Always	Usually	Not generally required
Sloughing	Intermittent	It varies	Continuous	Continuous	Continuous
Depth (m)	1.8 - 2.4	1.8 - 2.4	0.9 - 2.4	Up to 12	0.9 - 6
BOD removal (%) **	80 - 85	50 - 70	65 - 85	65 - 85	40 - 65
Effluent quality	Well nitrified	Some nitrification	Limited nitrification	Limited nitrification	No nitrification

* It does not include recirculation.

** Including secondary sedimentation.

2.- DESCRIPTION

Within the filter bed, the wastewater contacts with biofilm and air, allowing the air oxygen to dissolve in the liquid and to be transferred by diffusion in the biofilm with the nutrients present in wastewater. Also, the air comes into direct contact with the biofilm, since the bed should not be flooded.

Being an aerobic biological process, it is essential to allocate an air supply for the proper operation of the biofilm. In small installations the air supply may be performed by natural ventilation or shot. When the natural vent is insufficient, a forced aeration system may be used.

The wastewater entering the unit should be free of coarse solids that can clog the bed pores. As a general rule, wastewater is required to pass a pretreatment and a primary treatment.

The recirculation of treated effluent is common as operational tool to ensure bed moisturizing and to maintain an optimal treatment capacity. Furthermore it ensures that the concentration of BOD in the entrance of the bed is less than or equal to 150 mg/L. In addition to the prevention of odors and flies proliferation, it allows a wastewater adequate "application intensity" (see definition in section 3.5), both for normal operation of the process (clogging reduction) and for the control of excess biofilm detachment.

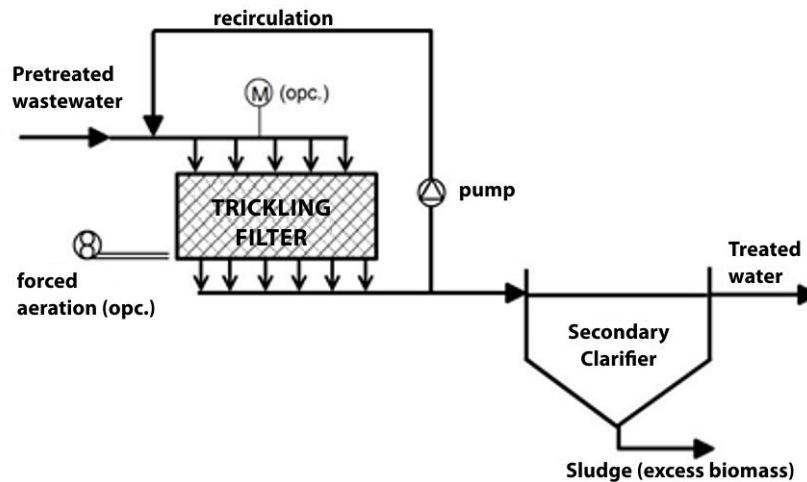


Figure 1.- General scheme of a trickling filter system

2.1.- Filling media characteristics

As biofilm support or bed filling media, plastic materials with different configurations are currently used, either as loose pieces filling the reactor randomly or arranged as evenly placed modules building up the filtering bed.

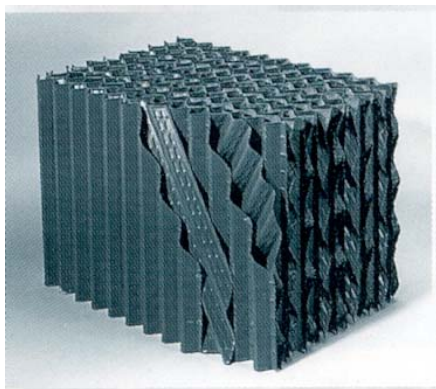
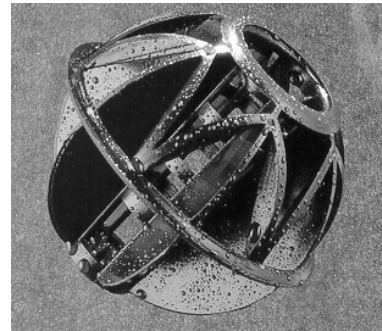


Figure 2.- Typologies of plastic support used as filling media for trickling filters

The main features related to the filling media are:

- Specific surface area: It is the support area available for the biofilm development per unit bed volume (m^2/m^3).
- Void ratio (porosity): Void fraction of the bed with respect to its total volume. It gives an idea of the space available for biofilm growth and water and air circulation. The greater the organic load is applied, the higher interstitial porosity must be as biofilm will be thicker.

Table 2.- Filling media characteristics in trickling filters

Plastic material	Size (cm)	Density (kg/m ³)	Specific surface area, A_s (m ² /m ³)	Porosity (%)	Removal of:
LOOSE PARTS	It varies It varies	32 - 64 48 - 80	85 - 110 130 - 140	> 95 > 94	C, CN, N N
STRUCTURED MODULE	60x60x120 60x60x120	32 - 80 64 - 96	85 - 110 130 - 140	> 95 > 94	C, CN, N N

C: Carbon BOD removal.

N: Tertiary nitrification.

CN: Combined nitrification.

2.2.- Wastewater distribution characteristics

Wastewater feed must be distributed as uniformly as possible throughout the bed surface:

- In rectangular beds, a fixed distribution system must be used, consisting of pipes and sprinklers.
- In circular beds a mobile system is used for the distribution of wastewater, comprised of a rotating central column, with radial branches where distribution nozzles (or simple holes) are installed. In this case, mechanical or hydraulical operation can be used in order to produce rotary motion.



Figure 3.- Left: Fixed wastewater distribution system. Right: Mobile wastewater distribution system of rotating arms on circular beds (<http://www.enviopro.co.uk>)

The filling of the filter is supported by a false bottom which allows treated water circulation. The tank floor is made with a 2% slope on the drainage channels direction. These channels can be interior and diametrical or peripheral. In the latter case the vessel wall has windows at its base around the entire periphery to permit the water outlet and bed aeration. Treated water and solids are fed into a secondary settling tank where the sludge is separated.

2.3.- Aeration characteristics

Traditionally, a natural draft for the ventilation of the beds has been used. The natural draft needs a temperature difference between air and water higher than 6°C in order to have an adequate operation.

When in a given period water and air temperatures are equal or quite approximate, air ventilation fails, the process performance decreases, odor problems occur, etc. For this reason, forced aeration is often used and covered beds usually incorporate air extractors.

In any case, there should be air openings in the lower part of the bed which represent at least a 2% of the bed surface to enable the air flow through the filter.

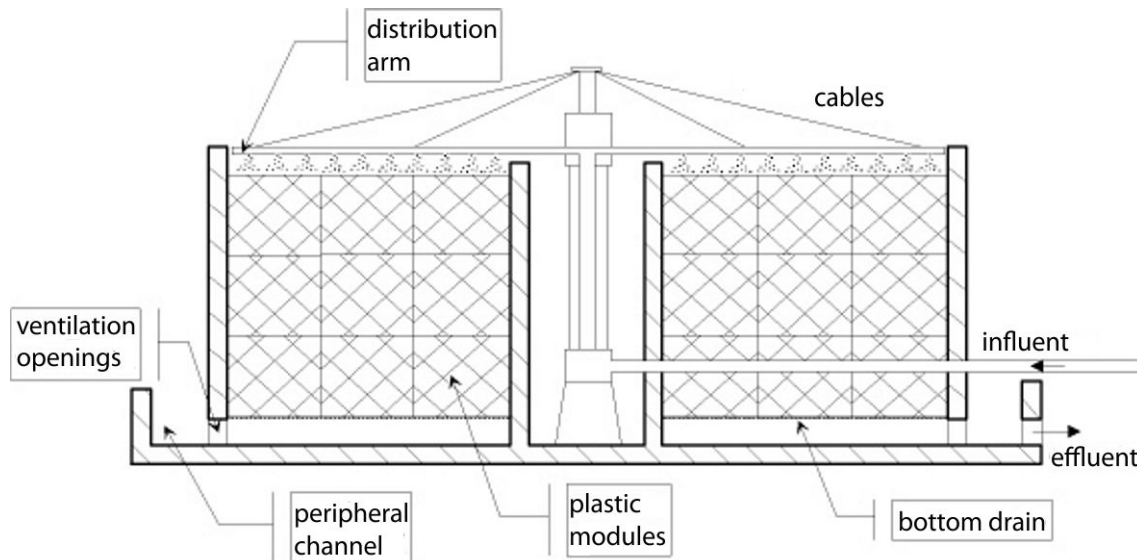


Figure 4.-Scheme of a circular bed with natural ventilation and plastic modules filling

3.- DESIGN

3.1.- Design parameters

Key design parameters are the organic load, the hydraulic load, the bed height and the recirculation rate. The organic load is estimated by using:

$$B_{V,BOD} = \frac{Q_{average} L_0}{V} \quad (\text{Ec. 1})$$

Where:

$B_{V,BOD}$ = organic load applied per unit bed volume (kg BOD₅/m³/d)

$Q_{average}$ = total daily average flow (m³/d)

L_0 = BOD₅ influent concentration average regardless recirculation (kg/m³)

V = bed volume (m³)

The hydraulic load rate is estimated by:

$$HLR = \frac{Q_{TF}}{A} \quad (\text{Ec. 2})$$

Where:

HLR = total surface hydraulic loading rate (m/h)

Q_{TF} = flow applied to trickling filter (m³/h) (it includes recirculation, see Ec. 4)

A = horizontal surface of the bed (m²)

The minimum bed height, H , required is given by:

$$H = V/A \quad (\text{Ec. 3})$$

3.2.- Sizing criteria

3.2.1.- Low and medium load beds

The organic load applied to flow rates up to 10 m³/d will be ≤0.1 kg BOD/m³/d. If flow rate is in the range between 10 and 40 m³/d, the organic load linearly increases from 0.1 to 0.2 kg BOD/m³/d. Between 40 and 400 m³/d, the load used as sizing criteria will increase linearly from 0.2 to 0.4 kg BOD/m³/d (see table).

The bed filling is made of plastic, with a specific surface not greater than 100 m²/m³.

The hydraulic loading rate with plastic filling beds should be at least 0.8 m/h, considering the following applied flow rate:

$$Q_{TF} = Q_{h,average} (1 + R) \quad (\text{Ec. 4})$$

Where R is the minimum recirculation ratio needed to achieve that the wastewater entering the bed to have a BOD_5 concentration lower than or equal to 150 mg/L. $Q_{h, average}$ is the hourly average flow (in m^3/h). An approximate method to estimate R is:

$$R \geq \frac{L_0}{150} - 1 \quad (\text{Ec. 5})$$

The filling height should never be less than 2 meters. If the bed height resulted from 2 to 4 m, it will be necessary a good distribution of the water over the bed surface, so it is desirable for the plastic filler to have a good lateral distribution of the flow in order to extend the contact time of the water through the bed.

Table 2.-Low and medium load design values for organic oxidation trickling filters

Parameter	$Q \leq 10 \text{ m}^3/\text{d}$	$Q \leq 40 \text{ m}^3/\text{d}$	$40 \text{ m}^3/\text{d} < Q \leq 400 \text{ m}^3/\text{d}$
$A_s (\text{m}^2/\text{m}^3)$ (plastic)	≤ 100	≤ 100	≤ 100
$L_{V,BOD} (\text{kg BOD}/\text{m}^3/\text{d})$	≤ 0.10	≤ 0.20	≤ 0.40
$HLR (\text{m}/\text{h})$	≥ 0.8 at $Q_{h,ave}$		
Bed $H(\text{m})$	Preferably ≥ 4 , never < 2 (max $H = 8 \text{ m}$)		

3.2.2.- Roughing filter

With the aim of a pre-treatment of the organic load achieving an organic removal yield of 40%. The organic load may range from 1.5 kg BOD/ m^3/d to 3.0 kg BOD/ m^3/d . The plastic filler clogging can be avoided by using a specific surface of 100 m^2/m^3 in the material.

3.3.- Application intensity (SK)

The distribution arms drive is an option to maximize the capacities of trickling filters.

The instant application intensity, or simply SK (*german* Spülkraft, washing power) parameter can be expressed in millimeters of water per distributor arm step:

$$SK = \frac{CH 1000}{n \cdot b \cdot 60} \quad (\text{Ec. 8})$$

Where:

- SK = Application intensity (mm/step)
- n = Spin speed (rpm)
- b = Distribution arms number

The following values for SK factor are proposed:

Table 3.- Recommended values for SK instant application rate

Organic load $\text{kg BOD}_5/\text{m}^3/\text{d}$	Optimum treatment SK mm/step	Periodic washing SK mm/step
≤ 0.40	10 - 50	≥ 100
1.0	30 - 200	≥ 300
2.0	40 - 250	≥ 400
3.0	60 - 300	≥ 600

As a general rule, it is suggested to perform the excess biofilm washing in low organic load periods.

It is also recommended that the range between distribution arms minimum/maximum drive speeds go from 1:10 to 1:20.



3.4.- Forced aeration

WEF-ASCE (1992) recommends, in case of beds for organic matter removal, a 25 kg O₂ supply per demanded kg O₂ (75 m³ of air per kg of oxygen demanded) regardless of the bed height.

$$I = 3.7 \times 10^{-3} \cdot Q_{ave} (L_0 - S_e) C_{p,global} \quad (\text{Ec. 9})$$

Where:

- I = Air supply (m³/h)
- L_0 = Influent total BOD₅ (mg O₂/L)
- S_e = Dissolved effluent BOD₅ (mg O₂/L)
- $C_{p,global}$ = Global peak coefficient = QH_p/Q_{ave} .

3.5.- Sludge production

The specific sludge production is proportional to the applied organic load. Considering loads between 0.10 and 0.4 kg BOD/m³/d, the specific production of sludge stands at 0.5 kg SS/kg of removed BOD₅. Above 0.4 kg BOD/m³/d, the sludge production is estimated by 0.75 kg SS/kg of removed BOD₅. In all these cases a secondary clarification is necessary.

Table 4.- Sludge production in trickling filters

Organic load (kg BOD ₅ /m ³ /d)	P_{sludge} (kg SS/kg BOD ₅)
0.10 – 0.4	0.5
> 0.4	0.75

*A sludge concentration of 1% is considered.

4.- SECONDARY CLARIFIER

In trickling filters, SS concentration at the outlet of the reactor does not usually exceed 150 mg/L, being able to apply the theory of flocculent particles settling. Static settlers are used for the clarification process. They may be rectangular or circular.

4.1.- Design variables

- **Hydraulic loading rate:** it is based on the real flow rate through the unit, that is, the discharge flow through the outflow weir.

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

Where:

- HLR = Hydraulic loading rate (m/h)
- Q = outflow (m³/h)
- A = horizontal clarification surface (m²)

- **Hydraulic retention time**

$$HRT = \frac{V}{Q_{max}} = \frac{A h}{Q_{max}}$$

Where:

- HRT = hydraulic retention time (hours)
- h = depth under weir (m)
- V = net clarification volume (m³)
- Q_{max} = maximum outflow (m³/h)

- **Hydraulic load over weir:** it corresponds to the effluent flow per linear meter of outflow weir.



$$OW = \frac{Q_{\max}}{L_w}$$

Where:

OW = overflow on weir ($\text{m}^3/\text{h}/\text{m}$)

L_w = weir length (m)

4.2.- Summary of design values

Table 5. Design values for secondary settling of trickling filters

Parameter	Value
Hydraulic loading rate (m^3/h)	$< 0.6 \quad (Q_{ave})$ $< 1.5 \quad (Q_{max})$
Hydraulic load over weir ($\text{m}^3/\text{h}/\text{m}$)	$< 10 \quad (Q_{max})$
Hydraulic retention time (h)	$> 1 \quad (Q_{max})$
Sludge concentration (%)	≤ 1
Minimum water depth under weir (m)	≥ 3.0

Clarifiers with truncated cone shape, also called vertical flow clarifiers. For technical and constructive reasons, the diameter will not be greater than 5 m.

The slope of the conical wall area responds to an angle greater than or equal to 60° (see figure below).

For these vertical flow clarifiers, the effective horizontal surface is set at the midpoint of the height between the unit water entry (that is, out of the central baffle) and the elevation of the free water level (see figure below).

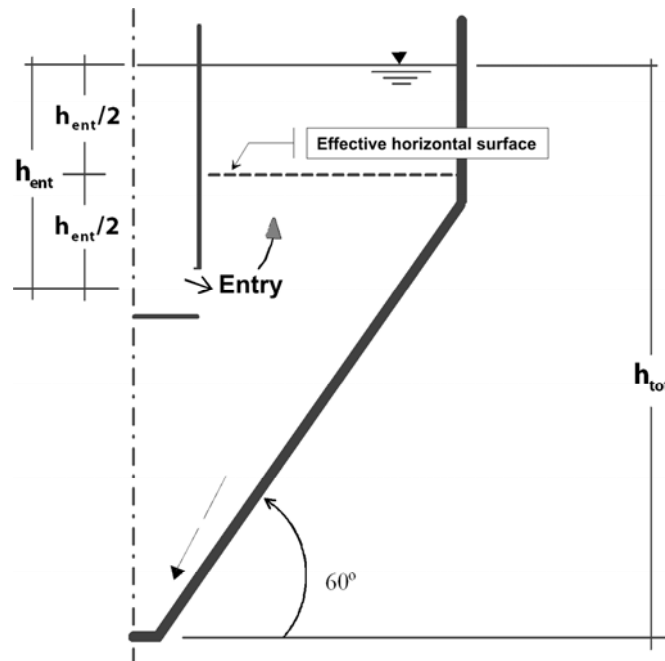


Figure 3.- Scheme of a vertical flow secondary clarifier (Adapted from DWA 2000)

5.- SPECIFIC TECHNICAL CONDITIONS

Trickling filters systems require pre-treatment of the wastewater. It is always recommended that the minimum degree of pretreatment is the primary treatment (e.g. settling). However, for flow rates up to 100 m³/d a pretreatment based on a rigorous coarse (20 mm) and fine screening (6 mm) may be sufficient.

In rectangular trickling filters the wastewater application system is fixed (non-moving) consisting of nozzles and sprinklers. Wastewater application can be performed intermittently, pumping wastewater from a storage tank; or continuously, by recirculation of the effluent.

When the filtering beds are circular and treatment flow is greater than or equal to 200 m³/d, distribution arms shall be provided with a mechanical drive like a variable speed motor.

For low load beds (flow rates below 40 m³/d), where recirculation is not normally used, the intermittent feeding (whether the bed is circular or rectangular) can be performed using siphon chambers or other mechanical devices (bucket type) providing a certain volume in each flow application to be evenly spread throughout the bed surface.

For flow rates from 50 m³/d, biological filters shall be provided with effluent recirculation. Using plastic carriers, with a porosity equal to or greater than 90%, the bed effluent may be directly recirculated, that means, without a settling step.

Regarding the secondary clarifier design, the following shall apply:

- The decanted water collection weir; it 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.

6.- SPECIFICATIONS IN THE TREATMENT OF WASTEWATER OF TEXTILE INDUSTRY

It is generally agreed that any organic waste, which can be successfully treated by other aerobic biological processes, can also be treated on trickling filters. This domestic wastewater and such wastewaters that might come from food processing, **textile** and fermentation industries, and certain pharmaceutical processes.

Industrial wastewaters, which cannot be treated, are those which contain excessive concentrations of toxic materials. For example, pesticide residues, heavy metals and highly acidic or alkaline wastes are all toxic materials.

An example of the applicability of trickling filters to wastewater related to the textile industry is the work of Kornaros and Lyberatos (2001) assessing a unit from an organic dyes manufacturing industry. Prior to the secondary treatment, wastewater is passed through a physical-chemical treatment using lime and ferrous sulfate. The trickling filter bed efficiency ranged between 60 and 70% for a hydraulic loading of 1.1 m³/m²/d and reached 80-85% for a hydraulic loading rate of 0.6 m³/m²/d. Bed microorganisms showed the capacity to efficiently remove COD levels up to 36000 mg/L under aerobic conditions at pH values between 5.5 and 8.0. Depending on the operating conditions of the system, approximately 30% to 60% of the total COD reduction was due to air stripping caused by the air supply at the bottom of the filter, while the rest of COD was removed clearly through biological action.

Others have studied trickling filters with mixed cultures of fungi and bacteria (Novotny et al., 2011). The low efficiency of dye removal by mixed bacterial communities and high discoloration rates by fungi (*Irpep lacteus*) suggest that a combination of these processes may be a treatment option for textile wastewater containing high concentrations of dyes and organic matter. The bacteria were able to remove mono-azo dyes but not other chemically different dyes; while decoloring rates using *Irpep lacteus* exceeded 90% in less than a week, regardless of the structure of the dye. A great potential use of combined fungi and bacteria traditional systems for bioremediation of textile wastewater was demonstrated.

7.- PARAMETERS AND CONTROL STRATEGIES

Once the biological growth has been established in the environment and the plant is in "normal operation", very little operational control routine is required.

A daily and detailed visual observation is important and necessary. Among the elements to check every day they are considered:

- Any evidence of surface flooding.
- Flies presence.
- Odors.
- Holes clogging in wastewater distributor-arms.
- Distributor-arms vibration.
- Leaks in the central feeding pipe.

Occasionally, the lower drain must be reviewed because of the possible accumulation of wastes in order to avoid stoppages.

Settlers operation is related to that of the filtering bed. If it is allowed by the recirculation system, it is a good idea to recycle the bed effluent to the primary clarifier. This is a very effective measure as an odors control strategy. The recirculation flow increases the hydraulic load in the primary settler, so the operator has to be sure that the hydraulic load is being maintained within design limits.

Recirculation during periods of low flow can help to: keep moist for the bacterial growth, minimize the development of flies and wash excess biofilm.

Moreover, it may be necessary to reduce or stop the recirculation during periods of high flow so as to avoid problems of hydraulic overloads on the secondary clarifier.

7.1.- Effluent control parameters

In the clarified effluent the level of organic matter (BOD, COD) and suspended solids (SS, turbidity) must be controlled.

Continuous probes can speed up and ease the process control by measuring both organic matter, through SAC-254 parameter, and suspended solids or turbidity.

In the case that forced ventilation is used, it shall be important to control dissolved oxygen (DO) concentration, using a DO probe. In larger plants, aeration is usually automated, so that, depending on the DO concentration, aeration equipment will start or stop. Also, if the equipment has an available frequency converter, the air flow supply can be regulated.

8.- OPERATION TROUBLESHOOTING

The following table lists a number of operational problems that could arise during the operation of a trickling filter. The table shows causes and solutions to problems or operational failures.

OPERATIONAL PROBLEM	CAUSE	SOLUTION
Odors	Excess organic load causing anaerobic decomposition in the filter	Reduce the organic load; increase BOD reduction in primary clarifiers; improve aerobic conditions in the processing units by adding chemical oxidants, pre-aeration, recirculation of the plant effluent, increased aeration in aerated grit chambers; gas treatment; use of plastic media instead of stone or gravel.
	Inadequate ventilation	Increase the hydraulic load to wash excessive biological growth; remove wastes from the effluent channel, from drainage and the top of the bed; unblock vent pipes; reduce hydraulic load if drains are flooded; install forced ventilation to induce air flue through the filter; check filter clogging resulting from environmental degradation.
Flooding the support material	Excessive biological growth or strange materials in/on the filter	Reduce organic load; increase the hydraulic load to increase biofilm detachment; wash the filter surface with high pressured water; maintain a concentration of 1 to 2 mg/L of residual chlorine in the filter for several hours; flood the filter for 24 hours; stop filtration in order to dry the bed; replace the support material if necessary; remove wastes.
Flies presence	Inadequate moist of the filter media	Increase hydraulic load; use the end-opening of the distributor-arms to spray the filter walls; flood the filter for several hours each week during the flies season; maintain a concentration of 1-2 mg/L of residual chlorine in the filter for several hours.
	Poor cleanliness of the environment	Cut the surrounding grass and remove weeds and shrubs.
Icing	Low wastewater temperature	Decrease recirculation; use high-pressured water to remove ice from holes, nozzles and distributor-arms; reduce the number of working filters as long as you can still meet effluent limits; reduce the retention time in pretreatment and primary treatment units; build windshields or covertures.
Distributor rotates slowly or stops	Insufficient flow distributor to move	Increase the hydraulic load; close back-spray orifices.
	Arms or holes are clogged	Open distributor-arm orifices; reduce solids in the influent; wash holes.
	Distributor vent pipe is clogged	Remove material from the vent pipe by washing or manually; reduce influent wastewater solids.
	Distributor-arms are not levelled	Adjust arm-holding cables.
	The distributor or any part of it hits or touches the bed.	Level the biofilm support material; remove some of the filling media.



BIBLIOGRAPHY

ATV-Standard A-135 (1989) "Principles for the dimensioning of Biological Filters and Biological Contactors with Connection Values over 500 Population Equivalents".

CANTER S. "Water World, Continuing education. Trickling filters" www.WaterWorldCE.com, diciembre 2014.

CRITES, R. y G. TCHOBANOGLOUS (2000) "Tratamiento de aguas residuales en pequeñas poblaciones". McGraw-Hill, Interamericana, S.A., Santafé de Bogotá, Colombia. ISBN 958-1-0042-4.

DAVIS, M. L. (2010) "Water and wastewater engineering. Design principles and practice". McGraw-Hill Companies, Inc. (USA).

GLUMRB (2004) "Recommended Standards for Wastewater Facilities", Great Lakes–Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers, Health Education Services, Albany, New York.

KORNAROS M. and LYBERATOS G. (2001). "Biological treatment of wastewaters from a dye manufacturing company using a trickling filter". 7th International Conference on Environmental Science and Technology Ermoupolis, Syros island, Greece – Sept. 2001.

METCALF & EDDY (1995) "Ingeniería de Aguas Residuales. Tratamiento, vertido y reutilización". McGraw-Hill – Interamericana, Madrid (España).

METCALF & EDDY (2003) "Wastewater Engineering: Treatment and Reuse", 4th ed., McGraw-Hill, Boston (USA).

MOPU (1978) "Anteproyecto para la redacción de proyectos de abastecimiento y saneamiento a poblaciones (NRPASP)". Ministerio de Obras Públicas y Urbanismo del gobierno de España. Documento no publicado. Madrid (España).

NOVOTNY C., SYOBODOVÁ K., BENADA O., KOFRONOVÁ O., HEISSENBERGER A., FUCHS W. (2011). "Potential of combined fungal and bacterial treatment for color removal in textile wastewater". Bioresource Technology 102: 879–888.

PETTIT, M. V. (2006) "Rectangular Clarifiers" in Clarifier Design, 2nd ed., Water Environment Federation Manual of Practice No. FD-8.

PRIDESA (1995) "Tratamiento biológico de las aguas residuales"; Autores: Ronzano, E.; Dapena, J.L.; Editorial Díaz de Santos; Madrid.

U.S. EPA (1992) "Manual of wastewater treatment/disposal for small communities". EPA/625/R-92/005. Washington, DC.

U.S. EPA (1992) "Summary Report. Small community water and wastewater treatment." EPA/625/R-92/010. Office of Research and Development. Washington, DC.

VESILIND, P. A. (2003) "Wastewater Treatment Plant Design", © Water Environment Federation. Alexandria, VA (USA).

WEF (2000). "Aerobic fixed-growth reactors". © Water Environment Federation, Alexandria, VA (USA).

WEF - ASCE (1992, 1998) "Design of municipal wastewater treatment plants"; Water Environment Federation; and the American Society of Civil Engineering; Volume I; 1592 págs.

WPCF (1986) "O & M of Trickling Filters, RBCs, and Related Processes" Manual of Practice OM-10, Operation and Maintenance Series". Water Pollution Control Federation, Technical Practice Committee Control Group; Alexandria, VA (USA).

ANNEX 1

REQUIRED SURFACE ESTIMATION

1.- SURFACE NEEDED FOR BIOLOGICAL REACTOR

The following table shows the amount of land required for a trickling filter (organic matter removal) for different sizes of the textile industry expressed in terms of average treatment flow. It is considered to be a pre-homogenization tank for flow and concentration equalization.

The main criterion for surface determination is the hydraulic load whose value is not less than 0.8 m/h.

The calculation considers the cases without recirculation ($R = 0$) and with effluent recirculation 50% ($R = 0.50$).

Table 1.- Minimum trickling filter surface

Flow	Surface	
	R = 0	R = 0.5
(m ³ /d)	(m ²)	(m ²)
400	21	31
800	42	63
2000	104	156

2.- SURFACE NEEDED FOR SECONDARY SETTLING

To estimate the necessary area for the secondary clarifier, the following design criteria are applied:

Hydraulic load rate to $Q_{ave} = 0.6$ m/h

Minimum flow = 3.00 m

The results are presented in the following table:

Table 2.- Required area needed for the secondary clarifier depending on the treatment flow.

Outflow	Area
(m ³ /d)	(m ²)
400	28
800	56
2000	139

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

Table 3. Total minimum surface required for secondary treatment (reactor + settling)

Flow rate	Area	
	R = 0	R = 0.5
(m ³ /d)	(m ²)	(m ²)
400	49	59
800	98	119
2000	243	295

ANNEX 2

GRAPHIC DESCRIPTION OF PROCESSING UNITS



Figure 1
Circular trickling filter gravel pack (from <http://www.purewatergazette.net>).



Figure 2
Detail of a distributor arm holes for waste outlet (from <http://www.enviroidynesystems.com>).

**Figure 3**

System for retaining and supporting the fill material of a trickling filter (from www.BrentwoodProcess.com, 05-08-09)

**Figure 4**

Detail discharge nozzle equipped with a primary and secondary arms bed, they start operating when the hydraulic load is high (from www.BrentwoodProcess.com)

**Figure 5**

Vari-Speed Control Systems for Operating Motor-Driven Units (<http://www.enviroidnesystems.com>).

**Figure 6**

Detail of an irrigation system used in wastewater rectangular bacterial bed (<http://www.ace4all.com>).

**Figure 7**

General appearance of a WWTP which includes four biological filters in parallel as a secondary treatment (<https://tatyalfiah.wordpress.com>).