2.1.3. Manual for Construction

Since last century, aerobic biological trickling filters have been used for treatment of waste water.

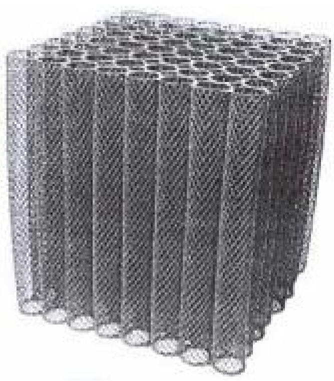
At first, a filter medium normally consisted of stones of different sizes, but recently, the stone medium has been replaced by a filter medium made of plastic units. Originally, the plastic medium had been developed for treatment of industrial waste waters with higher concentrations of organic matters than what is normally found in municipal domestic sewage.

In recent years, the use of biological filters has been modified so that they today to a higher extent are being used outside the normal concentration field of waste waters. Especially filter medium made of plastic has proven to be very suitable as primary treatment of industrial waste waters or waste waters from cities.

Biological trickling filters made of plastic have shown a great stability towards fluctuating supply of organic matters. Due to the great content of micro-organisms in the trickling filter, the filter is extremely resistant to occasional occurrences of toxins in the waste water.

In the light of this, the trickling filter is therefore with great advantage being used as highly loaded primary treatment plants for domestic sewage and industrial waste waters.

Supported by the Danish Trade and Industry Department, EXPO-NET Danmark A/S has developed a new, effective biological filter medium called BIO-BLOK®.



- BIO-BLOK® is made of polyethylene and complies with the most strict German, American and EU standards.
- BIO-BLOK® is constructed as a square block consisting of welded net tubes. The many net tubes with their special porous surface provides a big, accessible surface area, and at the same time, they improve the biological growth.

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By using BIO-BLOK® for trickling filters, the limits of hydraulic surface loads and organic loads have been moved because this modern filter medium does not have the same disadvantages as the old-fashioned stone filters do.

Depending on the treatment requirements, it is now possible to build up an effective trickling filter with very low working costs.

Below we will go briefly through the most important things concerning how to build up an effective trickling filter.

1. Theory concerning biofilm

In a biofilter, a thin membrane of micro-organisms will develop on this surface of the filter medium (BIO-BLOK®). This thin membrane is called a biological film (biofilm) The treatment of the waste water takes place when the waste water passes the biological film.

The principle of degrading of organic matters in a biofilm is shown below (please see Figure 1).

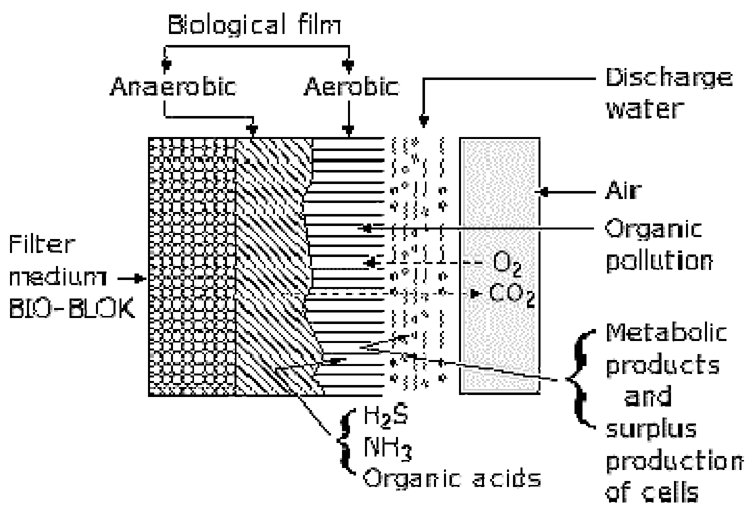

Figure 1: Schematic presentation of the treatment process in a biofilter (BIO-BLOK®)

When the waste water trickles down through the filter medium, the oxygen in the air is absorbed in the water and into the biofilm. The dissolved organic material in the waste water diffuses into the biofilm. This biofilm consists of micro-organisms which degrade the waste water into CO2 and water, and at the same time, new cells develop.

This process expends oxygen. Therefore, in a thick biofilm, oxygen free (anaerobic) conditions will exist in the part of the film that is closest to the filter medium. When the biofilm becomes too thick, it gets loose in flakes from the surface of the filter medium. The biofilm flakes thereafter settle in a succeeding sedimentation basin. New biofilm develops quickly.

It is thus a very simple and easy process which only depends on the form of the filter medium (BIO-BLOK®), the supply of waste water, and the temperature of the waste water.

2. Filter medium

The ideal filter medium has a big surface area per volume unit, is cheap, has a big mechanical strength, has a high percentage of hollow space, and has a structure that allows passage of loose biofilm through the filter.

Formerly different types of stone material were used as filter medium. In these filters, the percentage of hollow space was comparatively low. By high loads usually strong biological growth came into existence which resulted in clogging of the filters.

Today the dominant filter material is made of plastic such as e.g. BIO-BLOK® 100, BIO-BLOK® 150 and BIO-BLOK® 200.

EXPO-NET has made the following requirements on the filter medium:

- The surface has to have a roughness that permits the biological membrane to fix.
- The structure of the filter medium has to have such a form that a sufficient aeration of the filter can take place (a sufficiently high porosity).
- The structure of the filter medium has to have such a form that the washed off parts of the biofilm can pass through the filter.
- The filter medium has to be biologically undegradable.
- The filter medium has to be chemically undegradable.
- The filter medium has to be mechanically strong so that it can carry overlying material.

Today BIO-BLOK® 100, BIO-BLOK® 150, BIO-BLOK® 200 and BIO-BLOK® 300 meet all these demands.

With regard to the size and form of the filter medium, you work with qualities based on experience. The smaller filter material, the bigger contact area per volume filter medium. The lower limit of the size of the filter material is determined by the requirement that washed off parts of the biofilm should be able to pass through without clogging the filter.

Table 1: Technical specifications of BIO-BLOK®				
Type of filter media	**BIO-BLOK® 100**	**BIO-BLOK® 150 HD**	**BIO-BLOK® 200**	**BIO-BLOK® 300**
Specific surface (m^2/m^3) (approx.)	100	150	200	300
Area of flow (approx.)	70%	64%	60%	50%
Percentage of hollow space (approx.)	90%	88%	82%	65%
Tube diameter	70mm	55mm	55mm	30mm
Standard module form	54x54x55cm	55x55x55xcm	55x55x55cm	Loose tubes

The surface measurements have been calculated by the producer. Alterations in process, material and structure may slightly change the figures above (by up to 10%)). Above filter media are available with densities of approx. 0.5 and 0.95.

BIO-BLOK® 100, BIO-BLOK® 150 HD and BIO-BLOK® 200 are available in heights (lengths of block tubes) from 45cm to 75cm.

The Danish DanVand Centret tested BIO-BLOK® 100 as trickling filter on ordinary domestic sewage:

Photo 1: Test set-up - Odder Renseanlæg (treatment plant)

The results of this test were as follows:

- The biofilm establishes quicker on the filter material with the rough surface.
- The development of biofilm on the filter material is strong and attains approx. 160 kg/m^3.
- The efficiency of the filters is not proportionate to the biomass growth.
- The filters do not clog - even by high organic loads.
- In periods, a COD reduction corresponding to approx. 50g COD/m2 x day by a temperature of waste water of approx. 10^o C is obtained.
- The surface specific efficiency depends on the load.
- Even without nitrification, ammonia corresponding to 1.5% of the removed quantity of COD is removed.
- The filters have a high hydraulic capacity.

If requested, you can ask us for the report concerning above.

3. Pre-treatment of waste water

In ordinary biological trickling filters, it is not possible to treat the raw waste water directly. Therefore, a mechanical treatment of the inlet water is important if a regular operation of the trickling filter is to be ensured. The smaller content of suspended solids, the smaller a risk of a complete or partly clogging of the filter.

Therefore, the correct dimensioning of the mechanical treatment, which precedes a biological filter, is extremely important.

Should the mechanical treatment fail, the BIO-BLOK® 100 and BIO-BLOK® 200 can - through their construction - receive waste water with a high content of suspended solids without clogging. Thus, in this filter medium you have a dependability which is unique on the market.

This advantage makes it possible to construct treatment plants without any real pre-sedimentation basin, but only with a mechanical treatment of "grate matters" etc. before inlet into the trickling filter.

Examples of construction of biological treatment plants with trickling filters are shown in paragraphs 13.1 to 13.6.

4. Load

With regard to the load of a trickling filter, a distinction has to be made between the hydraulic surface load (HSL) and the organic volume load (OVL). The hydraulic surface load is defined as m3 waste water supplied to the filter per hour per m^2 surface of the trickling filter.

The unit of the hydraulic surface load is meter per hour and is sometimes referred to as the nominal filtration speed.

The hydraulic surface load cannot be chosen completely freely. Experience with trickling filters constructed with stones shows that the HSL may not be in the interval 0.1 to 0.8 meter per hour. The reason why is that not until by values above 0.8 meter per hour, a sufficiently high washing effect is reached to keep the filter clean. For values lower than 0.1 meter per hour, this is of no importance as the load is so low that the water can seep through the filter. Therefore, there is no lower limit for the hydraulic load.

However, it has turned out that by low loads, a big risk of filter fly attacks exists. This is due to the fact that the filter is not being sluiced regularly.

The upper limit is being fixed by the construction of the filter which determines the quantity of water that can run through the filter.

In connection with the upper hydraulic load of BIO-BLOK®, this is not known as the BIO-BLOK® can manage big volumes of water due to its construction. This means that it is always possible to wash the trickling filter clean. However, in order to secure the best form of biological treatment, it is extremely important that the water is dispersed as thinly as possible down through the filter.

The organic volume load is being fixed as follows:

Kg BOD5 supplied with the waste water per day per m^3 filter volume.
Regarding experience values for hydraulic surface loads and organic volume loads, please see Dimensioning (paragraph 10).

5. Height of filter medium

The importance of the height of the filter medium is not quite clear. Normally, an increase of the height of the filter gives an improved treatment of organic matters - probably due to the increased contact time.

Besides being important for the purification degree of organic matters, the filter height is important for the nitrification. Experience shows that the nitrification is improved with increasing filter height. Whether this is due to the longer contact time, the placing of the nitrifying bacteria in the filter, or the strong chimney effect (bigger supply of oxygen) has not been explained.

Based on experience, biological filters are normally being build in heights of 2 to 4 metres.

However, introducing BIO-BLOK® as a filter material, it is now possible to construct higher filters as the BIO-BLOK® products are made in self-supporting modules. Because of this, the BIO-BLOK® products do not require expensive tank constructions which makes the building up of trickling filters extremely cheap.

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When high trickling filters are being built, we draw your attention to the fact that the grating on which the filter medium stands is formed in such a way that the pressure does not destroy the filter medium and that water, sludge and air without hindrance can pass through the trickling filter and the grating.

See also Bottom construction (paragraph 7.1.).

6. Pressure tests of BIO-BLOK®

In connection with construction of biological trickling filters, submerged, biological filters, rainwater fascines etc. in which different types of BIO-BLOK® will be used, it is important to know how big a compressive stress these different types of BIO-BLOK® can be exposed to.

6.1. Structure of the pressure test

The BIO-BLOK® products have been pressure tested on a level surface and on a recently developed concrete grating which has been special-made to function as e.g. bottom in trickling filters. This grating has a big support surface, and at the same time, it is constructed in such a way that waste water and air can pass through the filter medium in an optimum way.

The support points are approx. 10 mm higher than the load-bearing grating. The maximum strength was read when these support points were pressed up into the BIO-BLOK® products.

Furthermore, the BIO-BLOK® products were pressure tested with side support on a level surface and also on the concrete grating. The end load was read when the maximum pressure was reached.

6.2. Conclusion

From the following data, it is obvious that the recently developed concrete grating has a positive effect on the deformations of the filter medium as this concrete grating has a large support surface. Even though the deformations increase somewhat, compared to a completely level surface - the deformations are very small.

A BIO-BLOK® exposed to small deformations will return to its original form as soon as the pressure has been removed.

It is also quite obvious that a BIO-BLOK® established with side support can absorb very big strengths.

Based on the test results, it can be concluded that trickling filters in all normal heights can be constructed with BIO-BLOK® products without destroying the filter medium.

It can also be concluded that the BIO-BLOK® products can be build into constructions where heavy pressure requirements are made on the filter medium.

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Table 2: BIO-BLOK® 100 and BIO-BLOK® 200 on filter grating													
		Compression in mm						**Load on grating**		**End load**			
BIO-BLOK	**Height in mm**	**300**	**500**	**800**	**1000**	**1500**	**2000**	**kg/BIO-BLOK**	**kg/m²**	**kg/BIO-BLOK**	**kg/m²**	**Side support**	**Notes**
100	550	8	14	24				900	2975	1100	3636	400mm	1
100	550	8	16					700	2314	800	2644	No	1
100	450	6	9	30				900	2975	1100	3636	400mm	1
100	450	6	10					700	2314	950	3140	No	1
200	550		4	6			13	3500	10769	4000	12755	400mm	1
200	550		3	8		12	17	2400	7933	2800	8928	No	1
200	450		4	8			16	2600	8595	4000	12755	400mm	1
200	450		5	8			13	2500	8264	3000	9566	No	1
100 Green	600		6	14		25		1500	4783	2100	6942	400mm	2

1. Almost no deformation by relief

2. Deformations

By load on grating, the strength has been read when the points on the grating are pressed up into the BIO-BLOK®.

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Table 3: BIO-BLOK® 100 and BIO-BLOK® 200 on level surface											
		Compression in mm						Load on grating			
BIO-BLOK	**Height in mm**	**300**	**500**	**800**	**1000**	**1500**	**2000**	**kg/BIO-BLOK**	**kg/m²**	**Side support**	**Notes**
100	650		10		25			1300	4297	500mm	1
100	650	10	16	28				800	2551	No	1
100	600	10	14	20				1300	4297	500mm	2
100	600	6	10	20				850	2710	No	2
200	650			7			10	3900	12892	500mm	2
200	650		4	7		13		2000	6611	No	2
200	600		5		10		14	4100	13553	500mm	2
200	600		2		7	10	17	2150	7107	No	2

1. Deformation does not disappear
2. Deformation partly disappears

7. Construction of trickling filter

7.1. Bottom construction

Normally, the biological trickling filters are constructed with two bottoms. The filter material is carried by the upper bottom. The bottom has to be amply supplied with slots or holes through which the treated water can pass downward and air for aeration of the waste water can pass for either upward or downward air flows.

For dimensioning of bottom grating, beams etc., the following units of weight of BIO-BLOK® and biofilm have to be calculated on:

* BIO-BLOK® 100 200 kg/m^3
* BIO-BLOK® 150 300 kg/m^3
* BIO-BLOK® 200 300 kg/m^3

Due to this and to bigger pressure requirements on BIO-BLOK® 100, BIO-BLOK® 150 and BIO-BLOK® 200, EXPO-NET has developed a concrete grating which has the following advantages:

* Creates an optimum dispersion of the pressure in the filter medium.
* Ensures a good dispersion of air in the filter medium.
* Creates optimum outlet conditions for filter sludge and waste water.
* An economically attractive solution as the filter gratings are constructed as elements.

7.2. Walls for trickling filter

The filter wall has to hold the filter material, protect it against cold winds and improve the natural draught so that the waste water can become aerated. At the same time, the wall has to be supplied with an adequate number of holes (minimum 8%) for passage of air for aeration of the waste water.

As the BIO-BLOK® products are constructed as self-supporting units, it is possible to save a lot of money with regard to construction of trickling filters. This means that it is possible to use light standard constructions instead of the normal concrete tanks.

The following material can be used for walls to trickling filters:

* Concrete elements
* Casted concrete tanks
* Steel sandwich elements

8. Dosage of waste water

In the infancy of the trickling filter, the filters were operated with discontinuous supply of waste water, i.e. a strongly varying operation. This has now been replaced by a constant operation as it has been acknowledged that a constant, even supply of water provides the best treatment results. Should the inflow of waste water be strongly varying, it is possible to recirculate the already treated water.

In new filters, recirculation is always used.

A recirculation can take place in two different ways. The first is a recycling of the settled humus sludge + some filtrated water to the inlet of the primary sedimentation basin. In this way the concentration of humus sludge is combined with a recirculation of treated water.

The other way of recirculation is to recirculate the secondary settled water to the inlet of the biological filter. These two ways of recirculation are shown below (see Figure 2.

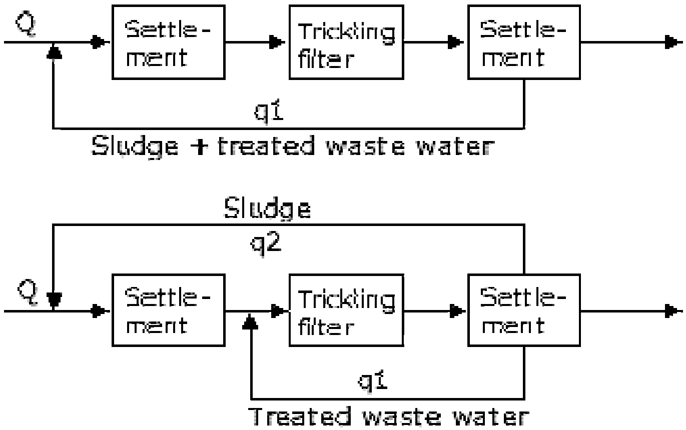

Figure 2 Ways of recirculation for biological trickling filters

The best way to spread the waste water over the filter medium can be done through rotating spreader arms. These require 0.5 to 1.0 meter water surface fall. The rotating arms are fixed on a vertical axle in the centre of the filter, and they either move by means of the water pressure or by means of a small motor.

Tests made in Norway and Sweden have shown that problems with lack of nitrification and attacks from filter flies are due to bad dispersal of the waste water in the trickling filter.

The correct hydraulic load on the trickling filter is being determined by the speed of the rotating arms that spread the water over the filter surface.

The rotating arms should not turn faster than the so-called SK-value is at least 40.

SK = (Vof x 1000) / (N x n x 60)

Where Vof = Volume of water per surface of the filter (m^3/m^2 x h)
N = Number of rotation arms of the spreader
n = Speed of rotation of the spreader (rotations per minute)

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Photo 2: Rotating arms spreading the waste water - Hjørring Renseanlæg (treatment plant)

The spreading of the waste water over the filter medium can also take place through fixed spreaders. Thus the pressure loss is avoided and the system becomes more energy friendly. By using fixed spreaders, it is also possible to construct trickling filters in rectangular tanks. Thus the system becomes more flexible and thus cheaper to run and establish.

9. Aeration

It is necessary to supply oxygen to the biological oxygenation processes. Normally, this happens by a chimney effect in the filter, however, in certain cases, a mechani-cal aeration can be necessary. High organic load, small differences of temperature between air and waste water, and protection of the filter against frost and the environment against filter flies are all factors that can necessitate a forced aeration of the filter.

By natural aeration, i.e. by chimney effect, the air flow can move both upwards and downwards. In the winter, the air in the filter, which has the same temperature as the waste water, is lighter than the surrounding air, therefore, the air flow moves upwards. In the summer, in the night the air flow moves upwards and in the day it moves downwards. By a difference of temperature of 6^{o} C, an air speed of approx. 0.3 m/min. occurs. This speed supplies sufficient oxygen for an oxygenation of organic matters, even in highly loaded filters.

Due to the special BIO-BLOK® construction, which consists of vertical, welded net tubes, optimum air flows in the filter medium can easier arise. This will increase the biological growth considerably and improve the treatment stability.

Because of the better chimney effect, all the air valves under the filter have to be shut when the temperature of the air becomes very low, if they are not shut, the risk of solid freezing of the filter exists. Therefore, in countries with cold winters, the trickling filters have to be force-aerated with warm air during winter time. Usually this air is "taken" from the outlet system.

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10. Dimensioning

Table 4: Ways of running a trickling filter			
	Low load	**Normal load**	**High load**
Organic volume load OVL (kg BOD5 / (m^3 x d))	0.1 - 0.3	0.5	2 - 10
Hydraulic surface load HSL (m3 / (m^2 x h))	0.1	0.8	2 - 20
Height, h (m) 0.1 - 0.3	2 - 4	2 - 10	2 - 10

Table 5: Typical values for decomposition speed in trickling filters by 15° C	
Removal of organic matters without nitrification	10 - 15g BOD7 / m^2 x d
Removal of organic matters and nitrification	4 - 8g BOD7 / m^2 x d
Removal of ammonia under oxygen reduction (> 3 mg NH4-N / l)	1 - 2g NH4-N / m^2 x d
Removal of ammonia under ammonium reduction (< 3 mg NH4-N / l)	0.1 - 0.7g NH4-N / m^2 x d

Table 5 can only be used as a guide as possible reactor design and hydraulic loads etc. of the filter have been disregarded.

Table 6: Decomposition figures for ordinary waste water			
Temperature	10° C	15° C	20° C
Decomposition of organic matters Organic surface load (g BOD5/m^2 x d)	13	17	20
Decomposition of ammonia down to approx. 3 mg NH4-N Ammonia surface load (g NH4-N/m2 x d)	0.9	1.2	1.6

EXAMPLE:

We want to dimension a trickling filter for nitrification down to 1 mg NH4-N / l in presettled waste water which contains 45 mg BOD5 / l and 25 mg NH4-N / l by a dimensioned volume of waste water of 1000 m3 water/h and a dimensioned temperature of waste water of 10^{o} C.

BIO-BLOK® 200 (surface area 200 m^2/m^3) is used as filter medium.

Necessary reactor volume for BOD decomposition:
VBOD = 45 x 1000 x 24 / (13 x 200) = 416 m^3 BIO-BLOK® 200

+

Necessary volume for oxygen reduced nitrification:
VN-O2 = (25 - 3) x 1000 x 24 / (0.9 x 200) = 2,934 m^3 BIO-BLOK® 200

=

Necessary volume for an outlet of 3 mg NH4-N / l: = 3,350 m^3 BIO-BLOK® 200

+

Necessary volume for ammonia reduced nitrification:
VN-NH4 = (3 - 1) x 1000 x 24 / (0.3 x 200) = 800 m^3 BIO-BLOK® 200

=

Total volume for an outlet of 1 mg NH4-N / l: = 4,150 m^3 BIO-BLOK® 200

11. Treatment degrees and decomposition figures

Table 7: Treatment degree (%) for domestic sewage

	Low load	High load	Very high load
BOD5	80 - 85	60 - 70	40 - 60
Nitrogen	10 - 15	5 - 10	5 - 10
Phosphorous	5 - 10	5 - 10	5 - 10
E.Coli	90 - 99	85 - 90	75 - 85
Virus	30 - 80	30 - 80	20 - 70
Metals	40 - 80	30 - 70	20 - 70

Table 8: Loads and decomposition for industrial waste water by means of trickling filters				
Type of waste water	**HSL m^3/m^2 x h**	**Organic load kg BOD5/m^3 x d**	**Treatment result in %**	**Decomposition g BOD5/m^2 x d**
Fruit industry	0.3 - 2.5	5 - 24.2	45 - 86	52 - 132
Canneries	0.05 - 1.4	0.74 - 10.5	41 - 80	7 - 52
Dairies	1.2	3.2	56	8.7
Potato industry		3.09	46	15.8
Slaughterhouse summer	1.4	1.65	88	6.4
Slaughterhouse winter	1.4	1.0	79	3.5
Slaughterhouse	1.05 - 14.7	0.43 - 3.22	41 - 59	3 - 16
Slaughterhouse	1.25	8.0	75	73
Slaughterhouse	0.34 - 15.7	2.48 - 83.2	42 - 61	18 - 426
Slaughterhouse	1.6 - 7.3	51.2 - 88.5	29 - 31	193 - 312
Sugar works	2.6 - 6.1	3.32 - 10.6	36 - 46	13 - 46
Shrimp peeling factory				
Fishing industry				
Slaughterhouse				

The big variation from place to place in volume and composition of the industrial waste water gives big variations in load and treatment results of the trickling filters. Therefore, experience values should only be used for rough calculations in the pre-project stage. Therefore, the final dimensioning of trickling filters should be based on pilot plants with the waste water in question.

12. Operation of trickling filters

Treatment plants constructed with trickling filters are considerably easier to operate than active sludge plants. This is due to the fact that the biofilm processes generally speaking are much less sensitive to hydraulic and organic load variations than the active sludge process.

The biofilm process can also work a longer time than the active sludge process by small or no loads.

The thickness of the biofilm adjusts itself exactly to the actual load. In a biofilter, the biomass establishes very quick after a state of low or no load. Besides a stable treatment process, this also means that biofilters are less sensitive to toxins in the waste water than active sludge plants are.

Due to the big variations in volumes of water and concentrations that can occur in treatment plants, biological trickling filters are extremely well-suited.

12.1. Sludge production

The sludge production in a biofilter plant depends on the organic load. Due to the fact that aeration of organic matters is not so effective by plants with high loads as by plants with low loads, filters with high load provide the biggest sludge production.

For plants with high load, it is normal to calculate with a sludge production of 0.6 -1.1 kg SS/kg decomposed BOD5. The mean value is estimated to be 0.8 kg SS/kg BOD5.

12.2. Clogging of filters

Clogging of trickling filters can occur in plastic filter medium with random packing, i.e. with filter medium that are loose.

Normally there are no problems with a modulate plastic medium with a big percentage of hollow space as e.g. BIO-BLOK® 100 and BIO-BLOK® 200. The plastic surface and the design of these net tubes result in the fact that surplus biofilm easily can pass through the filter.

BIO-BLOK® 100 is being used for very heavy waste water where heavy coating of biofilm can occur. Otherwise BIO-BLOK® 200 is used for the most common types of waste water.

In many cases preliminary sedimentation can be completely avoids as suspended solids easily can pass these types of filter medium.

12.3. Sedimentation

Biofilm from the filter medium settles quickly, but the sludge also contains floating sludge which can be difficult to settle.

Depending on the construction of the treatment plant, it is not always necessary to remove all the suspended solids in the waste water. In these cases, the sedimentation tank is dimensioned with a surface load of 1.5 - 2.5 m/h.

12.4. Addition of nutrients

In order to achieve an optimum biological decomposition in a trickling filter, nutrients have to be present in the waste water in the form of nitrogen and phosphorous.

A ration between BOD5 : N : P of approx. 100 : 5 : 1 is considered to be desirable.

As shown in Table 9, it is necessary to add nutrients to quite some types of industrial waste waters in order to achieve an optimum decomposition in trickling filters.

Table 9: Examples of different types of waste waters from industry

Type of industry	**BOD5 conc. in mg/l**	**BOD5 part dissolved in %**	**Addition of nutrients**
Bakery	1,000 - 2,000	60 - 70	N + P
Yeast production	1,000 - 2,000	80 - 90	N + P
Distillation production	1,000 - 2,000	90	N + P
Dairies etc.	500 - 2,000	60 - 70	N
Fish products	200 - 2,000	50 - 60	P
Slaughterhouses etc.	500 - 3,000	50 - 60	P
Fruit and vegatles industry	500 - 2,000	60 - 90	N + P

12.5. Recirculation

Biological trickling filters have to be constructed with possibilities of recirculation of the outlet water.

Recirculation of the waste water has the following advantages:

* Reduces the possibilities of clogging of the filter.
* Equalizes the load stops.
* Improves the distribution of the waste water and growth of biofilm.
* Quicker starting up.
* Dilution of toxic waste water.
* Keeps the biofilm wet and thus in function.

By treating concentrated waste water, recircualtion is necessary in order to achieve the optimum hydraulic load. A high trickling filter has a small cross-sectional area and a low degree of recirculation, but a high pumping height. A low trickling filter has a big cross-sectional area and a high degree of recirculations, but a low pumping height.

The recirculation itself has no positive effect on the treatment effect when treating easily degradable organic matters. When treating heavy degradable industrial outlet, the recircualtion can increase the treatment effect considerably.

Generally speaking, treatment plants should be constructed in such a way that recirculation of the waste water can be adapted after starting up of the plant.

12.6. Temperature of waste water

The biological activity in a trickling filter is influenced by the temperature in the same way as other biological treatment processes. The highest decomposition of micro-organisms in the trickling filter is achieved by temperature from 20^{o} C to 35^{o} C. This can be exploited by industries etc. which e.g. have big outlets of ventilation air by leading this warm air through the trickling filer. Thus a higher decomposition in the filter and a biological treatment of the air are achieved.

Trickling filters filled with plastic can function as cooling towers. In countries with a cold climate, big losses of heat can result in freezing of the trickling filters. As the micro-organisms work best by high temperatures of the waste water, it is important that the loss of heat is reduced most possible by insulation, covering, and ventilation control.

In countries with cold climate, in winter the trickling filters have to be forced-aerated with warm air from e.g. the conduction plant or the like.

On the other hand, in countries with warm climate, you will get an extremely effective treatment plant due to the warm air as the micro-organisms in the filter will get high speeds of decomposition.

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12.7. Supply of oxygen to waste water

In open trickling filter, normally a self-ventilation takes place due to the difference of temperature between the temperature of waste water and the temperature of air. The speed of air in the trickling filter depends on the difference of temperature. In the case of a high organic load and closed trickling filters (cold climate), a forced mechanical ventilation could be necessary. A volume of air corresponding to 20 times the volume of water running through is considered to be sufficient with regards to supply of oxygen from the air to the waste water.

12.8. Environmental inconveniences and remedy of these

By biological treatment of heavy waste water, trickling filters can cause obnoxious smells. These obnoxious smells are usually always due to little oxygen in the waste water so that a big part of the decomposition in the trickling filter is anaerobic (without oxygen).

This problem can be solved by doing as follows:

* Removing fat by means of a primary treatment of the waste water.
* Aerating the equalization tank.
* Avoid using preliminary sedimentation.
* Controlling pH and make sure that the correct ratio of nutrient is present.
* Ensuring sufficient aeration (supply of oxygen) through the trickling filter.
* Dimensioning the sedimentation tank for short residence time.
* Make frequent draining off of sludge from the sedimentation tank.

Another environment nuisance by running of trickling filters can be the growth of filter flies. This mass occurrence mostly occurs by temperatures above 15^{o} C. The fight against these can be done by improving the spreading of the waste water over the filter and possibly increasing the volume of water. Please, also see under Dosage of waste water (paragraph 8).