Biological Treatment of Waste Water by Filtration

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***Abstract*-Sewage treatment is the process of removing contaminants from waste water, including household sewage and runoff effluents. It includes physical, biological and chemical processes to remove contaminants. The objective of the sewage treatment is to produce an environmentally safe fluid waste stream or treated sludge suitable for disposal or reuse. There are number of biological treatment processes and technologies in literature and practice, however, for the purpose of this report, sewage filtration technologies are described. Since trickling filters only receive liquid waste, they are not suitable where water is scarce or unreliable. Compared to other technologies, trickling filters are compact, although they are still best suited for peri-urban or large, rural settlements. Trickling filters can be built in almost all environments, but special adaptations for cold climates are required.**

***Index Terms*-Biological treatment, Sewage, Trickling filters, Tertiary treatment**

1. INTRODUCTION

The Objective of the biological treatment of wastewater are to coagulate and remove the nonsettleable colloidal solids and to stabilise the organic matter. Biological treatment systems are living systems which rely on mixed biological cultures to break down waste organics and remove organic matter from the solution. Biological treatment systems are designed to maintain a large active mass of bacteria within the system confines. A treatment unit provides a controlled environment for the desired biological process.

Biological processes are classified by oxygen dependence of primary micro-organisms responsible for waste treatment. Biological processes may be (a) aerobic, (b) anaerobic, and (c) aerobic-anaerobic.

Aerobic processes are those which occur in the presence of dissolved oxygen. The aerobic process include the following: (i) Trickling filters; (ii) Activated sludge processes; (iii) Aerobic stabilization ponds; (iv) Aerated lagoons.

Anaerobic waste treatment involves the decomposition of organic or inorganic matter in absence of molecular oxygen. Anaerobic processes consist of the followings: (i) Anaerobic sludge digestion; (ii) Anaerobic contact processes; (iii) Anaerobic filters, and (iv) Anaerobic lagoons and ponds.

Aerobic-anaerobic processes are those in which stabilization of waste is brought about by a combination of aerobic, anaerobic and facultative bacteria. Most of the biological treatment processes are preferred to work on aerobic bacterial decomposition because such decomposition does not produce bad smells and gases as produced by anaerobic decomposition, and also because aerobic bacteria are about three times more active than anaerobic bacteria at 30□C.

2. BIOLOGICAL TREATMENT TECHNIQUES

The biological treatment techniques used may be classified under the following three heads:

(a) Attached growth processes (or fixed film processes), (b) Suspended growth processes, and (c) Combined processes.

(a) Attached growth processes: These are the biological treatment processes in which the microorganisms responsible for the conversion of the organic matter or other constituents in the wastewater to gases and cell tissue are attached to some inert medium, such as rock, slag or specially designed ceramic or plastic materials. Such processes include the following: (i) Intermittent sand filters; (ii) Trickling filters; (iii) Rotating biological contactors; (iv) Packed bed reactors; (v) Anaerobic lagoons (ponds); (vi) Fixed film denitrification.

(b) Suspended growth processes: These are the biological treatment processes in which the micro-organisms responsible for the conversion of the organic matter or other constituents in the wastewater to gases and cell tissue are maintained in suspension within the liquid in the reactor by employing either natural or mechanical mixing. In most processes, the required volume is reduces by returning bacteria from the secondary clarifier in order to maintain a high solids concentration. The suspended growth processes include the following: (i) Activated sludge processes; (ii) Aerated lagoons; (iii) Sludge digestion systems; (iv) Suspended growth nitrification and suspended growth denitrification.

(c) Combined processes: These consist of both attached growth processes as well as suspended growth processes. They include the following in sequence: (i) Trickling filter, activated sludge; (ii) Activated sludge, trickling filter; (iii) Facultative lagoons.

3. TYPES OF SEWAGE FILTERS

The action involved in sewage filtration consists of building up a few new compounds, which are stable, by combining with oxygen. Filtration satisfies the BOD of organic waste with the help of aerobic bacteria. The filter units used for biological treatment consist of open beds of coarse aggregates over which effluent from the primary clarifier is applied or sprinkled intermittently. In sewage filtration, mechanical action of filtration is very little only, since only the coarsest particles area arrested by the filtering media which oxidises and nitrifies the organic matter. The necessary contact surface, essential for the growth of aerobic bacteria, is provided by the aggregates in the bed and the aeration is provided by nature. The finer the filtering material, the larger is the total superficial area giving lodgment to the aerobic bacteria, but the possibility of clogging and reduction in the voids which supply the air are the factors which limit the size of the filtering media. The effluent from the filter units, containing stabilised new compounds, is settled out in secondary clarifiers. Common filters, used for sewage filters, are of the following 3 types : (i) Intermittent sand filters; (ii) Contact beds; (iii) Trickling filters.

3.1 INTERMITTENT SAND FILTERS

Intermittent sand filter, falling under the early developments of biological sewage treatment, consists of a layer of sand with an effective size of 0.2 to 0.5 mm, uniformity coefficient of 2 to 5 and of depth 75 to 100 cm. Sewage effluent from primary clarifiers is applied by means of a dosing tank and siphon. The effluent then escapes from the side opening of trough and ultimately, flows on the surface of sand bed. In order to facilitate the drainage of filtered effluent, a layer of about 15 cm to 30 cm depth of gravel is provided at the bottom of sand layer. To carry off the effluent, open jointed drainage pipes are laid in the gravel layer. The filters are generally rectangular in plan, with length to width ratio between 3 to 4, and area of each unit varying from 0.2 to 0.4 hectares. Usually 3 to 4 beds are provided adjacent to each other, so that they can work in rotation. Intermittent sand filtration is nowadays employed only for very small plants such as those for hotels, hospitals, or other social centres placed in remote areas where large area of land is available.

3.2 CONTACT BEDS

Contact beds, also called contact filters, are similar to intermittent sand filters in construction, except that the filtering media is very coarse, consisting of broken stone, called ballast of 20 to 50 mm gauge. A contact bed is a water tight tank of masonry walls and of rectangular shape. The depth of filtering media is kept between 1 to 1.8 m. The tank is generally dug below ground level and are lined with water - tight cement plaster, or of concrete surfaces instead of masonry. A siphonic dosing tank is provided to serve two or three contact beds. The effluent from primary settling tank is first received by the dosing tank and then distributed over one contact bed at a time. The effluent, after passing over the coarse filtering media is collected at the bottom and conveyed through the under drainage system to the effluent pipe which may be taken to secondary sedimentation tank for settling out the oxidized organic matter. The sewage is uniformly applied over the whole surface of a contact bed by means of distributing troughs having perforations/ outlets at regular interval.

The effluent received from contact bed is usually non-putresible, but is turbid and high in bacterial content. If effluent of better quality is required, the contact beds may be arranged in series, and the effluent from one contact bed is taken to the next one for further treatment and for better quality effluent.

3.3 TRICKLING FILTERS

Trickling filters, also known as percolating filters or sprinkling filters are similar to contact beds in construction, but their operation is continuous and they allow constant aeration. In this system, sewage is allowed to sprinkle or trickle over a bed of coarse, rough hard filter media, and it is then collected through the under drainage system. Spray nozzles or rotary distributors are use for this purpose. The biological purification is brought about mainly by aerobic bacteria which form a bacterial film, known as bio film, around the particles of the filtering media. The colour of this film is blackish, greenish and yellowish, and apart from bacteria, it may consist of fungi, algae, lichens, protozoa etc. For the existence of this film, sufficient oxygen is supplied by providing suitable ventilation facilities in the body of the filter and also to some extent by the intermittent functioning of the filter. The straining due to mechanical action of filter bed is much less. Organic removal occurs by biosorption from the rapidly moving part of the flow, and by progressive removal of soluble constituents from the more slowly moving portion.

The trickling filter is always preceded by primary sedimentation along with skimming devices to remove the scum. This will prevent the clogging of the filter by settleable solids. The effluent from the filter is then taken to secondary sedimentation tanks for settling our organic solids oxidised while passing through the filter. The secondary sedimentation tanks should also have skimming devices. The trickling filter serves both to oxidise and bioflocculate the organic matter in sewage and their efficiency is assessed on the total reduction in BOD effected through the filter and the subsequent settling tank, since the effluent quality is reckoned after the settlement of the bioflocculated solids.

BIOLOGICAL PROCESS IN A TRICKLING FILTER

Though, trickling filter is classified as an aerobic treatment device, the microbial film (or the biofilm) or the slime layer formed on the filter medium is aerobic to a depth of only 0.1 to 0.2 mm (Fig.1) and the remaining part of the film is anaerobic. As the wastewater flows over the microbial film, the soluble organic material in the sewage is rapidly metabolised while the colloidal organics are adsorbed onto the surface. In the outer portions of the biological film, the organic matter is degraded by the aerobic micro-organisms. Since food concentration is higher at the outer layer, the micro-organisms near the outer surface are in a rapid growth phase. As the micro-organisms at the outer surface grow, the thickness of the slime layer increases and the diffused oxygen is consumed before it can penetrate the full depth of the slime layer. Hence the lower zone of the film is in a state of starvation, due to which anaerobic environment is established near the surface of the media. As a result of having no external organic source available for cell carbon, the micro- organisms near the media surface enter into an endogenous phase of growth and lose their ability to cling to the media surface. Eventually, there is scouring of the slime layer due to flowing liquid and a fresh slime layer begins to grow on the media. This phenomenon of scouring of the slime is called sloughing or unloading of the filter.

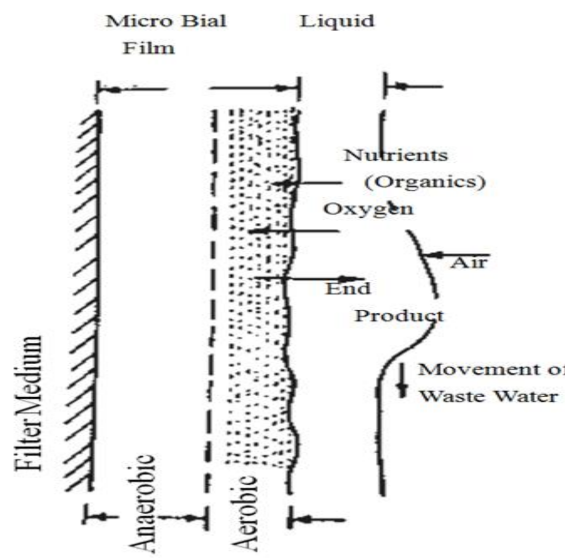

Fig. 1 - Schematic diagram of attached growth process in a trickling filter

CLASSIFICATION OF TRICKLING FILTERS

On the basis of hydraulic and organic loading rates, filters are usually divided into two classes: Low rate filters and (*ii*) High rate filters

Although there is no well defined practice, the ranges of loading usual for low rate and high rate filters are given in Table-1.

TABLE-I CLASSIFICATION OF FILTERS

S. No.		Hydraulic loading m3/d/m2	Organic loading g/d/m3
1.	Low rate filters	1-4	80 to 320
2.	High rate filters	10 to 30 (including recirculation)	500 to 1000 (excluding recirculation)

The hydraulic loading rate is the total flow including recirculation applied on unit area of the filter in a day while the organic loading rate is the 5-day 20OC BOD, excluding the BOD of the recirculant, applied per unit volume in a day.

USE OF TRICKLING FILTER

Trickling filters are used for biological treatment of domestic sewage and industrial wastes which are amenable to aerobic biological processes. They find use for complete treatment of moderately strong wastes and as roughing filter for very strong wastes prior to activated sludge units. Trickling filters possess a unique capacity to handle shock loads and provide dependable performance with a minimum of supervision. They are particularly suited for plants of capacities less than 5 mLd. The introduction of synthetic media has broadened the capabilities of the trickling filters in successfully treating industrial wastewaters. With synthetic media, trickling filters can handle higher organic and hydraulic loadings and can use deeper beds (up to 12 m.), this reduces the required land area.

CONSTRUCTION OF CONVENTIONAL TRICKLING FILTERS

Fig. 2 (a) and 2 (b) shows the cross-section through a slow rate trickling filter. It consists of (i) a water tight holding tank, (ii) distribution system, (iii) filter media, and (iv) under drainage system. The tanks is either square or rectangular in shape if fixed nozzles are used and circular is rotary distributors are used. As rotary distributors are more reliable and easy to maintain and operate, circular shape is most commonly use. The tank walls are made water tight. The distribution system spreads primary sedimentation tank effluent over a bed of filter media supported by a tile under drain system which also provides adequate ventilation.

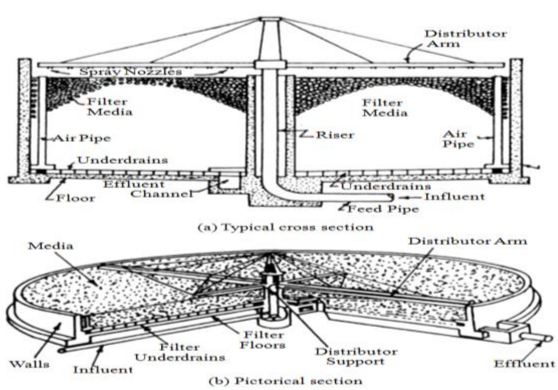

Fig. 2 - Trickling Filter

The walls of the tank are designed to withstand the pressure of sewage from inside. The under-drain system is supported by a floor which slopes to a collection channel.

Filter media: The filter media used for trickling filters should have high specific surface area; high percent void space, resistance to abrasion or disintegration during placement. Particles of filter media should be approximately round or cubical in shape and the filtering media should be free from flat or elongated pieces and should not contain dirt or any other undesirable materials. Not more than 5% of the media (by weight) should have the longest dimensions greater than 3 times the smallest dimension. The physical properties of filtering material are given in Table -2.

TABLE – II

PHYSICAL PROPERTIES OF FILTERING MATERIAL

Property	Desired value
1. Crusting strength	Not less than 100 N/mm2
2. Hardness	Not less than 12
3. Percent wear	Not more than 4
4. Specific gravity	Not less than 2.6

The filtering media should be washed before it is placed in position. The media should be placed and packed by hand for at least a height of 30 cm above the under-drainage system. The remainder of the material may be placed by means of wheel barrows or boxes or by belt conveyers.

Filter depth: It has been observed that the concentration of remaining impurities in sewage decreases as it passes downward through the filtering media. In other words, the effectiveness of filter decreases as depth increases. Hence the modern practice is to restrict the depth of filter and recirculate the effluent through the filter. For low rate operation, the filter depth usually varies from 1.8 m to 3.0 m.

Under-drainage System: The purpose of under-drainage system is two fold: (i) to carry away the liquid effluent and sloughed biological solids, and (ii) to distribute air through the bed. The under-drains cover the entire floor of the filter to form a false bottom and consist of drains with semicircular or equivalent inverts. They are formed of precast vitrified clay or concrete blocks, complete with perforated cover, or else they may be formed in-situ with concrete or brick and covered with perforated precast concrete slabs.

Main collecting channel: The main collecting channel is provided to carry away the flow from the under drains and to admit air to the filter. In a circular filter, the main channel may be located along a diameter, suitably curved around the central feed well or parallel to the diameter with a slight offset from the centre (Fig. 1). Alternatively, the channel may be provided along the periphery of the filter. In the former case, the channel shall be provided with perforated covers to enable drainage and also the ventilation of the filter media above the channel.

Filter floor: The filter floor should be strong enough to support the under-drainage system along with fully loaded superimposed filter media. The present practice is to provide a nominally reinforced cement concrete slab, 10 to 15 cm thick, over a proper leveling course. The slope of the floor towards the main collecting channel may be between 0.5 to 5%, usual value being 1%. Flatter slopes are provided in larger filters.

Filter walls: Filter walls may be either of fully plastered stone or brick masonry, or of reinforced concrete. For flooding operation, reinforced concrete is preferred. The walls of the filter are made honey combed or otherwise provided with openings for circulation of air, all through.

Distributor: The function of a distributor is to spread or spray the influent evenly on the surface of the trickling filter. This can be done from either fixed sprays or moving sprays. In the fixed sprays, used for rectangular tanks, the sewage is sprinkled through stationary nozzles connected to a network of pipes. However, fixed nozzle distributors are no longer used. The moving sprays system may be either of longitudinal travelling type or rotary distributor type. Among the moving types, the longitudinal travelling distributors (used for longitudinal or square tanks) are not popular in the country because of long resting period associated with their time of travel from one end of the bed to the other and the need for reversing the gear at each end of the bed to change the direction of motion. The present practice is to provide circular tanks and to use only reaction type rotary distributors (Fig. 2).

4. RESULTS AND DISCUSSIONS

HIGH RATE TRICKLING FILTERS

Trickling filters are conventional aerobic biological waste water treatment units. The advantages of these units are that they are compact and they efficiently reduce organic matter. To increase the rate of filter leading high rate trickling filters are used.

The basic difference between high rate trickling filter and slow rate or conventional trickling filter is that the rate of filter loading (both hydraulic as well as organic) of the former is several times more than that of the latter. The main effect of the conventional trickling filter is that it has high initial cost, it requires large are of construction and it requires large quantity of filtering media. Experiments conducted on trickling filters with increasing rate of sewage flow revealed the following:

1. As the sewage flow is increased, the thickness of the gelatinous biofilm is reduced and the organic materials deposited on the contact surface is continuously washed away with the effluent.
2. Thinner biofilm is more efficient and supplies more continuous nutrients to the aerobic bacteria.
3. The precipitation and biological coagulation of the dissolved and colloidal matter is more or less of the same degree as in normal rate filters.
4. However, there is lesser oxidation of organic matter because of reduction in the contact period.
5. Since large quantity of unloaded putrescible organic material reaches the secondary settling tank, the load on the secondary settling tank is increased.
6. The sludge produced as a result of high rate filtration is not easily digestible.
7. The cost of construction and land etc. decreases with the increase in rate of filtration.

Due to the above favourable observations, high rate trickling filters have become more popular, and they have replaced conventional trickling filters in many countries. To achieve high rate filtration, the following modifications are made to the conventional or slow rate trickling filters.

1. Better quality filtering material is used, so as to give higher specific surface. The recent trend is towards the use of larger size stone media, or to use plastic synthetic media.
2. The depth of filter media is reduced to about 1.5 to 2.0 m, so as to obtain better aeration in order to obtain high rate of biological activity.
3. The size of under-drains is increased and their

slope is also made steeper so that the filter effluent can be collected and conveyed to the secondary settling tank quickly.

4. The speed radiation of the rotating arm is increased to 2 rps for increased hydraulic loading.
5. The size of secondary settling tank is also correspondingly increased to cope with the increased quantity of flow and bio-flocculent solids coming out with the trickling filter effluent.

Filter media: The size of filter media is of considerable significance as the specific surface decreases with increase in media size but the percent void space increases, as indicated in Table - 3.

TABLE – 3
PHYSICAL PROPERTIES OF TRICKLING FILTER MEDIA

Media	Size (mm)	Unit weight(kg/m3)	Specific surface (m2/m3)	Void space (%)
Granite	25-75	1440	62	46
Granite	100	1440	47	60
Slag	50-75	1090	67	49
Plastic sheet	600 x 600 x 1200	32-96	82-115	94-97
Red wood slats	1200 x 1200 x 500	165	46	76

Advantages of high rate filters:

(1) Since smaller filter volume is required, initial cost is less.
(2) Operating costs are also low.
(3) The trouble of bad smell or odour is much less.
(4) The working is flexible. Hence the efficiency or filter is not seriously affected due to variations in the strength and character of sewage.

Disadvantages:

(1) The effluent is not highly nitrified. Hence the effluent from the system requires more volume of dilution water.
(2) Raw sewage cannot be treated and the process requires primary treatment of sewage.

5. TRICKLING FILTER TROUBLES AND REMEDIES

Following are common troubles occurring at the site and operation of trickling filters:

(a) Fly nuisance*:* Slow rate trickling filters often become infested with small moth like, deceptively fragile flies called 'Psychoda'. These flies do not bite, but may get into the eyes, nostrils and ears of men and animal. Its size is so small that it can even enter through the window mesh or screens. The flies lay their eggs in the filter and the wormlike larvae feed upon the filter by constantly consuming the dead and dying zoological masses. Heavy infestation is associated with thick films and high temperatures.

Remedial Measures: (1) Flooding the filter for about 24 hours, at weekly or biweekly intervals. (2) Jetting down the inside walls of the filter with a high pressure hose. (3) Chlorinating the filter influent (0.5 to 1.0 mg/l) for several hours at one to two week intervals. (4) Application of larvicide such as D.D.T., chlordane, malathion etc. when the filter is not in operation. These should be applied to the filter side walls and surface at intervals of 4-6 weeks. Development or resistant strains should be guarded against. (5) Continuous hydraulic loading to hamper the flies and larvae. (6) Sprinkling lime at the site and at all possible places where its larvae are breeding.

(b) Odour nuisance*:* Odours from filter are due to undesirable growth, sludging and anaerobic decomposition. Odours are most serious when treating septic effluents in low rate filters using rotary distributors, but they are more common when fixed nozzles are used.

Remedial measures*:* (1) Maintaining a well ventilated filter, either by natural ventilation or by forced ventilation. (2) Recirculation of filter effluent or secondary clarifier effluent, which will wash fine solids through the filter bed, dilute the influent sewage and add dissolved oxygen. (3) Aeration or chlorination of sewage before primary settling of sewage.

(c) Ponding nuisance: This nuisance is caused when all the voids of the trickling filters are filled up due to choking by heavy fungus or other suspended matters, due to which the sewage cannot pass through the filter and accumulate at the surface in the form of pond. Ponding decreases filter ventilation, reduce the effective volume of the filter and reduce filter efficiency. Ponding or clogging is due to excessive organic loading, inadequate hydraulic loading and inadequate size of media.

Remedial measures*:* (1) Opening the clogged section by flushing with a fire hose and simultaneously loosening the aggregates by a steel bar. (2) Reducing the strength of filter influent by re-circulation. (3) Flooding the filter once in a day and allowing of it to stand for 24 hours. (4) Chlorinating the influent with a dose not exceeding 5 kg/100 m2 of filter area, once in every 4 to 7 days. This may be done at night when sewage flow is low. (5) Stopping the distributor over the ponded area. (6) Keep the filter out of operation for 12 to 48 hours. (7) Reduction of the recirculation flow, adjustment of nozzle or construction of wind breakers are methods used to reducing icing problems.

6. CONCLUSIONS

Waste Water Treatment processes are designed to achieve improvements in the quality of waste water by removing or reducing suspended solids, biodegradable organics, pathogenic bacteria and nutrients (including nitrates and phosphates). There are three levels of waste water treatment: primary, secondary, and tertiary (or advanced).

Primary (mechanical) treatment is designed to remove gross, suspended and floating solids from raw sewage. It includes screening and sedimentation. Primary treatment can reduce the BOD of the incoming wastewater by 20-30% and the total suspended solids by some 50-60%.

Secondary (biological) treatment removes the dissolved organic matter that escapes primary treatment. This is achieved by microbes consuming the organic matter as food, and converting it to carbon dioxide, water, and energy for their own growth and reproduction. The biological process is then followed by additional setting tanks to remove more of the suspended solids. About 85% of the suspended solids and BOD can be removed by secondary treatment. Secondary treatment technologies include trickling filters and other forms of treatment which use biological activity to break down organic matter.

Tertiary treatment is simply additional treatment beyond secondary! Tertiary treatment can remove more than 99 percent of all the impurities from sewage, producing an effluent of almost drinking-water quality. The related technology can be very expensive, requiring a high level of technical know-how and well trained treatment plant operators, a steady energy supply, and chemicals and specific equipment which may not be readily available. Disinfection, typically with chlorine, can be the final step before discharge of the effluent. However, some environmental authorities are concerned that chlorine residuals in the effluent can be a problem in their own right, and have moved away from this process. Disinfection is frequently built into treatment plant design, but not effectively practiced, because of the high cost of chlorine, or the reduced effectiveness of ultraviolet radiation where the water is not sufficiently clear or free of particles.

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