13. Trickling Filters

13.1 Theoretical Background

Trickling filter is a fixed film secondary treatment process wherein the organic content of the wastewater is removed using biological growth attached to an inert media such as lava rock or plastic

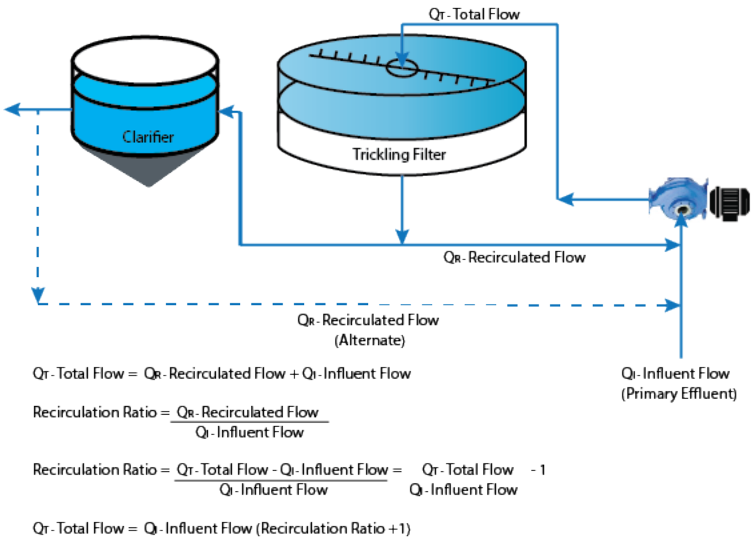
- In a trickling filter, the wastewater is sprayed evenly on the surface of the media with a rotary type distributor with orifices
- The wastewater percolates through the media bed, where it comes in contact with biological slime growth – zoogleal film (zooglea)
- The aerobic biomass - bacteria, protozoa and other microoorganisms in the zooglea capture and consume the suspended and dissolved organics from the wastewater.
- The microorganisms metabolize the organics and in the process produce more microbial mass resulting in increasing the thickness of the zoogleal layer.
- The thickness of the zoogleal layer can only increase to a point until the wastewater flow – hydraulic load, shears the slime layer – "sloughs off" and is carried out as part of the effluent flow as sloughing.
- The treated wastewater cascades from the bottom of the media into the underdrain system – lower portion of the TF comprised of columns which support the media base. The underdrain has a sloping floor to direct the cascading water into a center channel .
- The clarifier allows for the separation (settling) of the of the solids (sloughed off material). The settled solids is removed - typically pumped to a digester and the clarified effluent flows out of the clarifier.
- The source of oxygen to support the aerobic growth is from the oxygen dissolved in the wastewater as it is sprayed over the media and from the air currents due to the downward flow of the wastewater and the temperature difference between ambient and the interior of the trickling filter. Forced ventilation system may be designed as part of the trickling filter
- Word trickling "filter" is a misnomer - no filtration is involved
- Advantage includes process simplicity and lower costs
- Disadvantage include BOD removal efficiency of only about 80-85
- The media may be rock, slag, coal, bricks, redwood blocks, molded plastic, or any other sound durable material.
- The media depth ranges from about three to eight feet for rock media trickling filters and 15 to 30 feet for synthetic media.
- The media needs to be uniformly sized and have adequate empty spaces (voids) to ensure maintain-

ing aerobic condition necessary for the survival of biomass.

- Pre-fabricated (synthetic) media - similar to the one shown below, has an advantage over the "dumped" type media such as lava rock of providing a greater surface area per volume upon which the zoologeal film may grow while providing ample void space for the free circulation of air.
- Sometimes, due to inadequate hydraulic loading, portions of the zoogleal layer may become too thick and oxygen cannot penetrate its full depth, causing odor issues.

13.2 Trickling Filter Recirculation

Recirculation - where a portion of the treated wastewater is returned back as the feed to the TF. The parameter recirculation ratio is calculated to quantify the recirculation flow. Recirculation ratio is a ratio of the recirculated flow - Q_R to the influent flow Q_I. Recirculation ratios typically vary from 0.5 to 4.



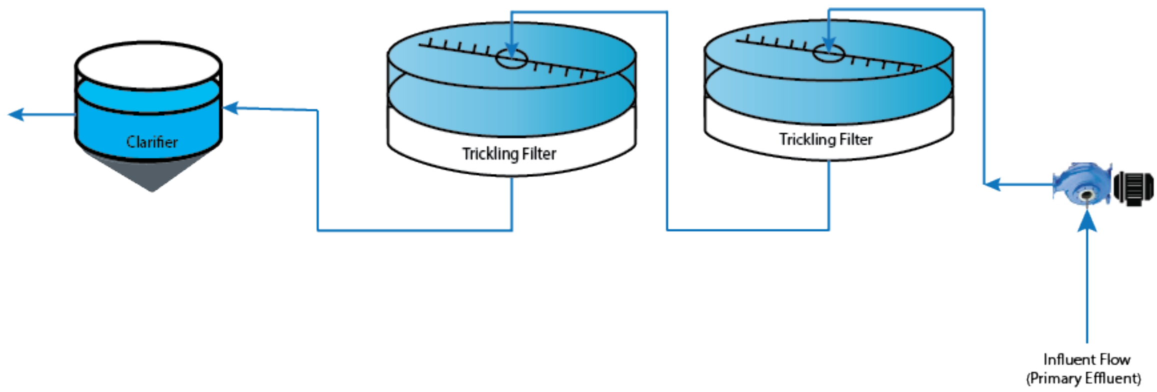
Recirculation is beneficial for the following reasons:

- It improves the removal efficiency by increasing the contact time of the zoogleal layer with the wastewater
- During low flows it prevents the trickling filter from drying out
- It dilutes any toxic loadings
- It promotes oxygen transfer and reduces ponding
- The increased hydraulic loading promotes uniform sloughing, prevents ponding, improves ventilation through the filter and reduces potential for snail and filter fly breeding

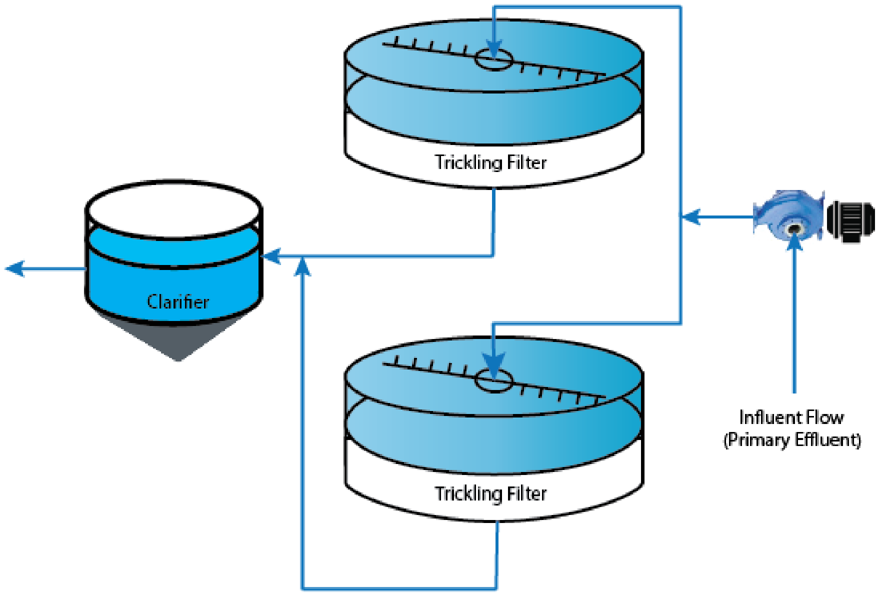
13.3 Operation of Multiple Trickling Filters

Multiple trickling filters can be operated in series or in parallel:

- Series operation in which the flow from one flows into the next.



  - For high strength loading and for nitrification
- Parallel operation in which the trickling filters that are operated side by side.



  - For winter operation - prevents freezing in the TF

13.4 Parameters for monitoring and operating trickling filters

1. Hydraulic loading is expressed as gpd/ft^2
2. BOD Removal (%)
3. Organic loading lbs BOD/day/ 1000 cu ft
4. Recirculation ratio

13.5 Classifying Trickling Filters

Trickling filters are classified according to the hydraulic and organic loading applied to the filter

13.5.1 Low-rate filter

- The standard rate or low rate trickling filters (LRTF) are relatively simple treatment units that normally produce a consistent effluent quality even with varying influent strength
- They are generally not provided with recirculation of effluent
- Depending upon the dosing system, wastewater is applied intermittently with rest periods which generally do not exceed five minutes at the designed rate of waste flow.
- While there is some unloading or sloughing of solids at all times, the major unloadings usually occur several times a year for comparatively short Periods of time.

Hydraulic loading is 25 - 100 gal/day/sq. ft
BOD Removal (%) 50 – 80%
Organic loading is 5 - 25 lbs BOD/day/1000 cu ft

13.5.2 High-rate filter

- The most important element of a high-rate trickling filter is the provision where a part of the settled treated effluent is pumped to the PST or to the filter. This is termed as **Recirculation**
- High-rate filters are usually characterized by higher hydraulic and organic loadings than low-rate filters
- The higher BOD loading is accomplished by applying a larger volume of waste per unit surface area of the filter.
- As a result of the higher flow velocities a more continuous and uniform sloughing of excess zoogleal growth occurs

Hydraulic loading is 100 - 1000 gal/day/sq. ft
BOD Removal (%) 65 - 85%
Organic loading is 25 - 100 lbs BOD/day/ 1000 cu ft

13.5.3 Roughing filter

- Roughing filters are high rate type filters designed with plastic packing
- In most cases roughing filters are used to treat wastewater prior to secondary treatment
- One of the advantages of roughing filter is low energy requirement for BOD removal of high strength wastewaters as compared to activated sludge process because the energy required is only for pumping the influent wastewater and recirculation flows

13.6 Trickling Filter Operational Issues

13.6.1 Ponding

If the voids in the media get plugged, flow can collect on the surface in ponds. Correction: spraying the surface with high pressure water stream stopping a rotary distributor over the ponded area hand-stir the media or open the voids dose the filter with chlorine for several hours

13.6.2 Odors

- Corrective measures should be taken immediately if foul odors develop
- presence of foul odors indicates anaerobic conditions are predominant
- Check the under drain system for obstructions or heavy biological growths
- increase the recirculation rate to provide more oxygen to the filter bed and increase sloughing
- keep slime growths off of sidewalks and inside walls of the filter to reduce the odor

13.6.3 Trickling Filter Flies - Psychoda

- tiny, gnat-size filter fly, or Psychoda - primary nuisance insect
- Correction methods include
  - Increase recirculation rate
  - keep orifice openings clear
  - apply insecticides to filter walls
  - dose filter with chlorine
  - keep weeds and tall grass cut around filter

13.6.4 Cold weather problems

- ice can form on the media of the filter
- Correction methods include:
  - decrease recirculation to the filter (influent is usually warmer than recycled flows)
  - construct wind screens
  - operate two-stage filters in parallel rather than in series

13.7 Math Problems

Trickling filter problems involve calculation of the following:

13.7.1 Hydraulic or surface loading

- Hydraulic or surface loading is expressed as gpd/ft^2
- The gpd is the total flow (Q_T)to the filter - primary influent flow + recirculated flow(Q_T= Q_I + Q_R)

Example Problem:
The total influent flow (including recirculation) to a trickling filter is 1.89 MGD. If the trickling filter is 80 ft in diameter, what is the hydraulic loading in gpd/sq ft on the trickling filter?

Solution:

$$Hydraulic\ \ loading\ \ \frac{gpd}{ft^2} = \frac{(1.89 * 10^6)gpd}{(0.785 * 80^2)ft^2} = \boxed{376\frac{gpd}{ft^2}}$$

13.7.2 BOD and TSS Removal

BOD and removal is based upon the TF influent and effluent concentrations.

$$\%Removal = \frac{In_{conc} - Out_{conc}}{In_{conc}} * 100$$

Example Problem:
The suspended solids concentration entering a trickling filter is 236 mg/l. If the suspended solids concentration of the trickling filter effluent is 33 mg/l, what is the suspended solids removal efficiency of the trickling filter?

Solution:

$$\%Removal = \frac{236mg/l - 33mg/l}{236mg/l} * 100 = \boxed{86\%}$$

13.7.3 Organic Loading

- Organic loading to a trickling filter is typically expressed as lbs BOD/(day-1000 cu ft).
- The lbs/day BOD value is the BOD loading from the primary effluent.
- The 1000 ct. ft is the volume of the media.
- The media volume is calculated by multiplying the TF surface area by the media height.
- As the dimensions are typically given in ft., calculate the volume in ft^3 and then divide the calculated volume by 1000 to give the volume in units of $1000ft^3$

Example Problem:
A trickling filter, 70 ft in diameter with a media depth of 6 ft, receives a flow of 0.78 MGD. If the BOD concentration of the primary effluent is 167 mg/L, what is the organic loading on the trickling filter in lbs BOD/day/1000 cu ft?

Solution: $Organic\ \ loading : \frac{lbs\ \ BOD}{day - 1000ft^3} = \frac{lbs\ \ BOD\ \ feed\ \ to\ \ TF\ \ per\ \ day}{volume\ \ in\ \ 1000ft^3}$

$$= \frac{\frac{(0.78 * 167 * 8.34)lbs\ \ BOD}{day}}{(0.785 * 70^2 * 6)ft^3 * \frac{1000ft^3}{1000ft^3}} = \boxed{\frac{47lbs\ \ BOD}{day - 1000ft^3}}$$

13.7.4 Recirculation Ratio

$$Recirculation\ \ Ratio(R_R) = \frac{Recirculated\ \ Flow(Q_R)}{Influent\ \ Flow(Q_I)}$$

$$Recirculation\ \ Ratio(R_R) = \frac{Total\ \ Flow(Q_T) - Influent\ \ Flow(Q_I)}{Influent\ \ Flow(Q_I)}$$

$Total\ \ Flow(Q_T) = Influent\ \ Flow(Q_I) * (Recirculation\ \ Ratio(R_R) + 1)$ Make sure Q_R, Q_T and Q_I units are the same in a given problem

Example Problems:

1. The influent to the trickling filter is 1.61 MGD. If the recirculated flow is 2.27 MGD, what is the recirculation ratio?

   Solution: $R_R = \dfrac{Q_R}{Q_I} = \dfrac{2.27}{1.61} = \boxed{1.4}$

2. A trickling filter has a total flow of 32 MGD. If the recirculation ratio is 0.8, what is the primary effluent flow to the TF?

   Solution:

   $$Total\ \ Flow(Q_T) = Influent\ \ Flow(Q_I) * (Recirculation\ \ Ratio(R_R) + 1)$$
   $$\implies 32MGD = Q_I * (0.8 + 1) \implies Q_I = \frac{32}{1.8} = \boxed{17.8MGD}$$