Example Solved Problems on Trickling Filters

Sewage Treatment and Disposal

Design suitable dimensions of a circular trickling filter unit for treating 5 million litres of sewage per day. The BOD of sewage is 150 mg/l.

PROBLEMS

5. Design suitable dimensions of a circular trickling filter unit for treating 5 million litres of sewage per day. The BOD of sewage is 150 mg/l.

Solution:

Total BOD of sewage = 5 MLD × 150 mg/l

= 5 x 10^6 × 150 mg/l

10=750 kg/d.

Note: After primary treatment 30% of BOD is removed, so only 70% BOD enters the trickling filter.

Assume organic loading = 1500 kg/ha-m/day. (range is 900 to 2200 kg/ha-m/d)

Volume of filter media = Total BOD of sewage / Organic loading rate

= 750kg/d /1500kg/ha-m/d

= 0.5ha-m.

=5000m^3

Assume effective depth of filter as 2 m.

Surface area of filter required = Volume of filter media / Effective depth of filter

$$= \frac{5000 m^3}{2m} = 2500 \text{ m}^2.$$

$$\frac{\pi}{4} d^2 = 2500$$

$$d = \sqrt{\frac{2500 \times 4}{\pi}}$$

$$= 56.4 \simeq 57 m.$$

Circular trickling filter of diameter 57 m.

$$\text{No. of units } = \frac{\text{Total area required}}{\text{Area of single unit}}$$

$$= \frac{2500 m^2}{\pi/4 \times 57^2} = 1 \text{ Unit.}$$

Check for Hydraulic Loading (22 to 44 ML/ha/day).

Surface area required = Total sewage treated/day)/Hydraulic loading/day

5 MLD / 22 ML/ha/d = 0.2 ha

S.A =0.2 ha = 2000 m^2.

S.A = 0.2 ha = 2000 m^2. [1 hectare = 10,000 m^2]

Surface area chosen is 2500 m^2 > 2000 m^2. Hence safe.

(or)

$$\text{Hydraulic loading rate} = \frac{Q}{A} = \frac{\text{Total sewage treated/day}}{\text{Surface Area}}$$

$$= \frac{5 \text{ MLD}}{2500 m^2} = \frac{5 \times 10^3 m^3/d}{2500 m^2}$$

$$= 2 \text{ m}^3/\text{d}/\text{m}^2.$$

$\boxed{\text{Value should be within } 1 - 4\ m^3/d/m^2. \text{ Hence O.K.}}$

Efficiency of Filter (if required)

$$\eta = \frac{100}{1 + 0.0044\sqrt{u}}$$

u = organic loading in kg/ha-m/d

u = 1500 kg/ha-m/d

$$\eta = \frac{100}{1 + 0.0044\sqrt{1500}}$$

η = 85.4%.

6. AHRTF of 15 m ϕ operated with primary effluent of 1500 m3/d, recirculated effluent flow 1000 m3/d. Calculate recirculation factor and hydraulic loading rate on filter.

Solution:

$$R = \frac{\text{Recirculated flow}}{\text{Sewage influent}} = \frac{1000\ m^3/d}{1500\ m^3/d} = 0.67.$$

$$F = \frac{1+R}{[1+0.1R]^2} = \frac{1+0.67}{(1+0.1\times 0.67)^2} = 1.47.$$

$$\text{Hydraulic loading rate} = \frac{Q}{A} = \frac{1500\ m^3/d}{\frac{\pi}{4}\times 15^2\ m^2} = 8.49\ m^3/d/m^2$$

In high rate trickling filter, rate of hydraulic loading ranges between 10 to 30 $m^3/d/m^2$.

7. The sewage is flowing at 4.5 ML per day from a primary clarifier to a standard rate T.F. The 5-day BOD of influent is 160 mg/L. The value of adopted organic loading is 160 g/m^3/d. Surface loading is 2000 l/m2/d. Determine volume of filter and depth. Calculate efficiency of filter unit.

Solution:

Total 5-day BOD in sewage

$$= 160\ mg/l \times 4.5 \times 10^6\ l/d$$

$$= 720000\ g/d.$$

$$\text{Volume of filter media} = \frac{\text{Total BOD}}{\text{Organic loading rate}} = \frac{7,20,000\ g/d}{160\ g/m^3/d}$$

$$= 4500\ m^3.$$

Surface area required for filter

$$= \frac{\text{Total flow}}{\text{Hydraulic loading rate}}$$

$$= \frac{4.5\times 10^6\ l/d}{2000\ l/m^2/d}$$

$$= 2250\ m^2.$$

$$\text{Depth} = \frac{\text{Volume}}{\text{Surface area}} = \frac{4500\ m^3}{2250\ m^2} = 2\ m.$$

u = Organic loading in kg/ha-m/d

Organic loading = 160 g/m^3/d

$$= 160 \times \frac{10^4}{10^3}\ \text{kg/ha-m/d}$$

$$= 1600\ \text{kg/ha-m/d}$$

$$\eta = \frac{100}{1+0.0044\sqrt{u}} = \frac{100}{1+0.0044\sqrt{1600}}$$

$$= \frac{100}{1.176} = 85.3\%$$

$$\boxed{\eta = 85.3\%.}$$

8. A single stage filter is designed for an organic loading of 1000 kg of BOD in raw sewage per hectare metre per day with a recirculation ratio of 1.2. This filter treats a flow of 4 MLD of raw sewage with a BOD of 220 mg/l. Using NRC formula, determine strength of effluent.

Solution:

Flow = 4 MLD

BOD = 220 mg/l.

Total BOD-raw sewage = Flow x BOD concentration

$= (4 \times 10^6)(220 \times 10^{-6})$

= 880 kg/d.

Total BOD-Raw Sewage/ Organic loading rate

880 kg/d / 1000kg/ha-m/d = 880 m^3.

Assume 35% BOD removal in primary clarifier.

BOD of influent applied to filter = 0.65 x 880 = 572 kg.

Efficiency of filter, E = 100 /1+0.44√U

U - kg/m^3/d.

$$V = \frac{W}{V.F} \qquad W - BOD$$

$$W = 572 \text{ kg/d} \qquad V - \text{Volume}$$

$$V = 880 \text{ m}^3 \qquad F - \text{Recirculation factor.}$$

$$F = \frac{1+R}{(1+0.1R)^2} = \frac{1+1.2}{(1+0.1\times1.2)^2} = 1.754$$

$$E = \frac{100}{1+0.44\sqrt{W/VF}} = \frac{100}{1+0.44\sqrt{\frac{572}{880\times1.754}}}$$

$$E = 0.789.$$

$$\text{Total BOD of effluent} = (1-0.789) \times 572$$

$$= 120.65 \text{ kg.}$$

$$\text{BOD conc of effluent} = \frac{120.85\times10^6}{4\times10^6} \text{ mg}/l$$

$$= 30.21 \text{ mg}/l.$$

Note: In case the previous design was two stage trickling filter, then what would be the BOD of effluent?

Total volume of filter remains the same.

Filter volume of single stage = Filter volume of two stage (two filters)

Recirculation ratio of each filter = 1.2.

R = 1.2

F = 1.754.

First Stage:

$$\text{Efficiency,} \quad E = \frac{100}{1+0.44\sqrt{\frac{W}{VF}}}$$

$$= \frac{100}{1+0.44\sqrt{\frac{572}{440\times1.754}}}$$

$= 72.53\%.$

Volume of first stage filter $= \frac{1}{2}$ of single stage filter

$$= \frac{880}{2} = 440 \text{ m}^3.$$

BOD of effluent from first stage = BOD of influent to second stage

$$= (1 - 0.7253) \times 572 = 157.15 \text{ kg/d}.$$

Second Stage:

$$E' = \frac{100}{1+\frac{0.44}{(1-e)}\sqrt{\frac{W'}{V'F'}}}$$

$W' = 157.15$ kg/d $\quad e = 0.7253$

$V' = \frac{880}{2} = 440 \text{ m}^3$;

$F' = 1.754.$

$$E' = \frac{100}{1+\frac{0.44}{(1-0.7253)}\sqrt{\frac{157.15}{440\times1.754}}}$$

$= 58.05\%.$

Total BOD of effluent from plant

$= 157.15\,(1 - 0.5805)$

$= 65.95$ kg/d.

BOD conc. of effluent $= \frac{65.95\times10^6}{4\times10^6}$

$= 16.48$ mg/l.

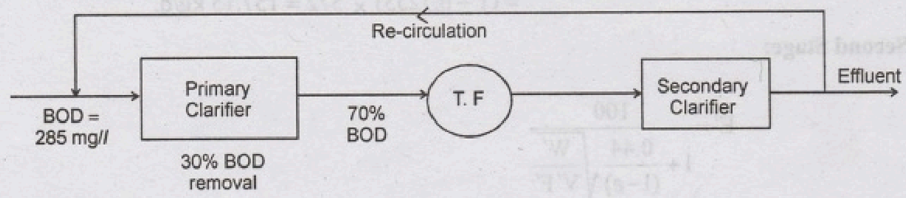
9. Design a HRTF for treating domestic sewage with a BOD of 285 mg/l and average flow of 40 MLD. The effluent BOD desired is 10 mg/l. Use NRC equation.

Solution:

Flow = 40 MLD = 40×10^3 m^3/d.

30% BOD removal from primary clarifier

$$BOD = \frac{0.7 \times 40 \times 10^6\, m^3/d \times 285}{10^6}\ mg/l = 7980\ kg/day.$$



HRTF – Organic loading = 500 to 1000 g/d/m^3

$$= 0.8\ kg/d/m^3.$$

$$\text{Volume of trickling filter} = \frac{\text{Total BOD in sewage}}{\text{Organic loading rate}}$$

$$= \frac{7980\, kg/d}{0.8\, kg/d/m^3} = 9975\ m^3.$$

Adopt two units

$$\text{Volume of each unit} = \frac{9975 m^3}{2} = 4987.5\ m^3.$$

Assume depth of media = 2 m.

$$\text{Surface Area} = \frac{\text{Volume}}{\text{Depth}} = \frac{4988}{2}\ \frac{m^3}{m} = 2494\ m^2$$

$$\frac{\pi}{4} d^2 = 2494\ m^2$$

$$\boxed{d = 56\ m.}$$

Assume recirculation ratio of 2.

$$\text{Recirculation factor} = \frac{1+R}{(1+0.1R)^2}$$

$$= \frac{1+2}{(1+0.1\times 2)^2}$$

$$F = 2.083.$$

Load on stage 1 T.F, $W_1 = 7980$ kg/d.

$$\text{Efficiency of 1}^{st}\text{ stage, } E_1 = \frac{100}{\left(1+0.44\sqrt{\frac{W}{VF}}\right)}$$

$$= \frac{100}{1+0.44\sqrt{\frac{7980}{4988\times 2.083}}}$$

$$= 72.17\%$$

Influent BOD = $0.7 \times 285 = 199.5$ mg/l

Effluent BOD = 10 mg/l.

$$\text{Total BOD removal efficiency} = \frac{199.5-10}{199.5}\times 100 = 94.98\%.$$

Efficiency of 2nd stage

$$E_2 = E - E_1$$

$$= 94.98 - 72.17$$

$$= 22.81\%$$

BOD load on second stage T.F.

$$W_2 = (1 - 0.7217) \times W_1$$

$$= (1 - 0.7217) \times 7980$$

$$\boxed{W_2 = 2220.83\ kg/d.}$$

R = 2, F = 2.083.

Using NRC equation,

Efficiency of 2nd stage T.F.

$$E_2 = \frac{100}{1 + \frac{0.44}{(1-E_1)}\sqrt{\frac{W_2}{V_2 \cdot F}}}$$

$$22.81 = \frac{100}{1 + \frac{0.44}{(1-0.7217)}\sqrt{\frac{2220.83}{V_2 \times 2.083}}}$$

$$1 + 1.58\sqrt{\frac{1066.16}{V_2}} = 4.384$$

$$\sqrt{\frac{1066.16}{V_2}} = 2.142$$

$$\boxed{V_2 = 232.37 \text{ m}^3.}$$

Assume depth = 2 m.

$$\text{Area} = \frac{\text{Volume}}{\text{Depth}} = \frac{232.37}{2} = 116.18 \text{ m}^2$$

$$\frac{\pi}{4} d^2 = 116.18$$

$$\boxed{d = 12.16 \text{ m} \simeq 12.50 \text{ m}}$$

Results:

Ist stage T.F = 56 m ϕ

IInd stage T.F = 12.50 m. ϕ

10. Determine the size of a high rate trickling filter for the following data:

(i) Sewage Flow = 4.5 MLD

(ii) Recirculator Ratio = 1.5

(iii) BOD of raw sewage = 250 mg/l

(iv) BOD removal in primary tank = 30%

(v) Final effluent BOD desired = 30 mg/l

Solution:

Quantity of sewage flowing into the filter per day = 4.5 MLD

BOD concentration in raw sewage = 250 mg/l

.. Total BOD present in raw sewage = 4.5 Ml x 250 mg/l

1125 kg.

BOD removed in primary tank = 30%.

BOD left in sewage entering per day in the filter unit = = (1125) × 0.7 = 787.5 kg.

BOD concentration desired in final effluent = 30 mg/l

.. Total BOD left in the effluent per day = 4.5 x 30 kg

BOD removed by the filter = 135 kg.

Efficiency of the filter = 787.5 - 135 = 652.5 kg.

Efficiency of the filter $= \frac{\text{BOD removed}}{\text{Total BOD}} \times 100$

$$= \frac{652.5}{787.5} \times 100 = 82.85\%$$

Using NRC equation

$$\eta = \frac{100}{1+0.0044\sqrt{\frac{W}{VF}}}$$

$$\eta = 82.85\%$$

$$W = \text{Total BOD in kg}$$

$$= 787.5 \text{ kg}$$

$$F = \frac{1+R}{(1+0.1R)^2} = \frac{1+1.5}{(1+0.1\times1.5)^2}$$

$$= 1.89$$

$$\therefore\ 82.85 = \frac{100}{1+0.0044\sqrt{\frac{787.5}{V\times1.89}}}$$

$$V = 0.2 \text{ hectare-}m$$

$$= 2000\ m^3.$$

Assuming depth of filter as 1.5 m.

$$\text{Surface Area} = \frac{\text{Volume}}{\text{Depth}}$$

$$= \frac{2000}{1.5} m^2$$

$$= 1333.3\, m^2$$

Diameter of Circular Trickling Filter

$$\text{Surface Area} = \frac{\pi}{4} d^2 = 1333.3 m^2$$

$$d = 41.2 \text{ m.}$$

Hence, provide a high rate trickling filter of 41.2 m diameter, and 1.5 m depth of filter media.

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