Basic Environmental Engineering and Pollution Abatement
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Lecture 35
Tutorial 7

Hello everyone, now, we will have a tutorial session, and we will solve some numerical problems based on the discussion in our four previous classes.

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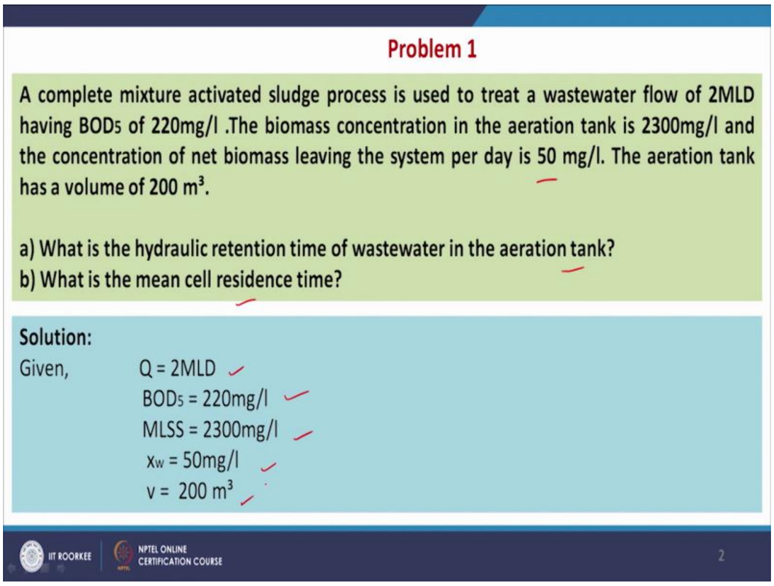

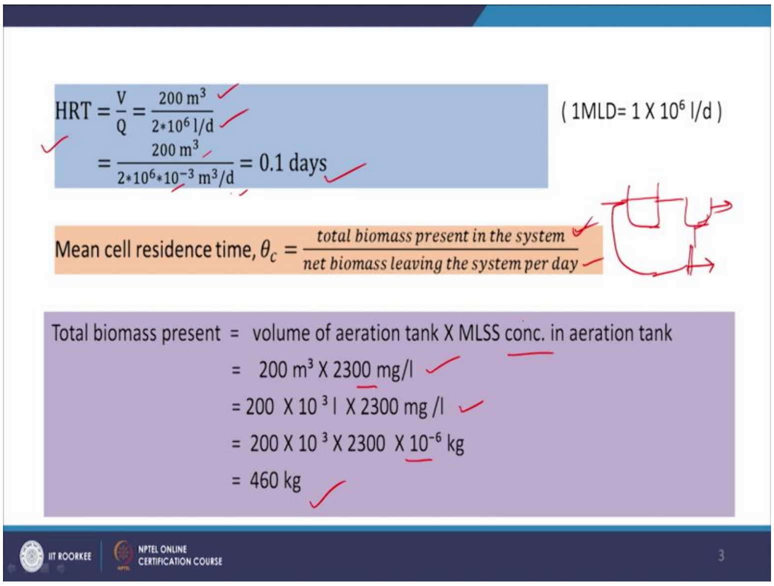

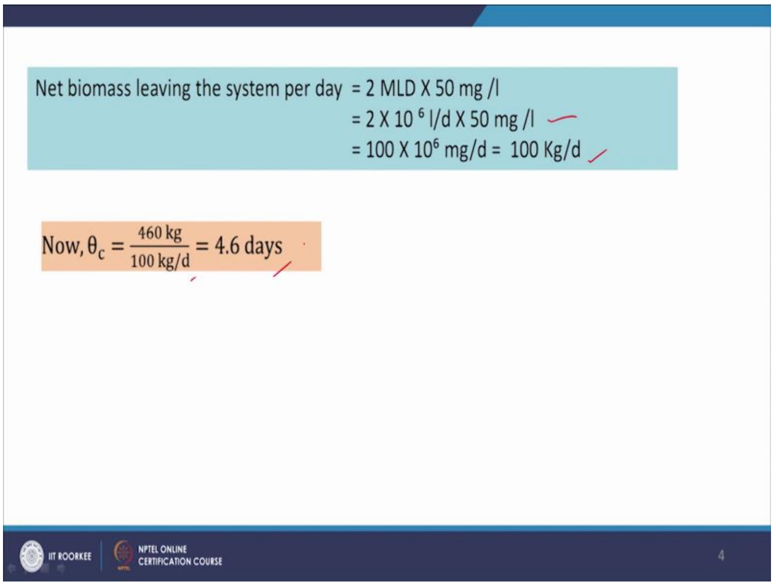

Problem number 1, the statement is a complete mixture, activated sludge process is used to treat a wastewater flow of 2MLD having BOD5 of 220 mg/l, the biomass concentration in the aeration tank is 2300 mg/l, and the concentration of net biomass leaving the system per day is 50 mg/l, the aeration tank has a volume of 200-m^3. So, what is the hydraulic retention time of wastewater in the aeration tank? And what is the mean cell residence time? So, these two we have to calculate on the basis of the statement.

So, here we have Q that is volumetric flow rate = 2MLD

BOD_5 = 220 mg/l

MLSS 2300 mg/l

Xw = 50 mg/l,

V = 200-m^3

So, these parameters are given in the statement. So, this is a problem of secondary treatment using activated sludge process. So, we will be using the formula we have discussed in the previous class like say for example, the HRT, hydraulic retention time.

$$\mathrm{HRT} = \frac{V}{Q} = \frac{200\ m^3}{2*10^6\ l/d}$$

Where, V is the reactor volume, the volume of the aeration tank and Q volumetric flow rate.

$$\mathrm{HRT} = \frac{200\ m^3}{2*10^6*10^{-3}\ m^3/d} = 0.1\ \text{days}$$

$$\text{Mean cell residence time } \theta_c = \frac{\text{biomass present in the system}}{\text{net biomass leaving the system per day}}$$

Total biomass presents in the system = volume of the aeration tank * MLSS, concentration in the aeration tank

$= \quad 200\ m^3 \text{ X } 2300\ mg/l$

$= 200 \text{ X } 10^3\ l \text{ X } 2300\ mg/l$

$= 200 \text{ X } 10^3 \text{ X } 2300 \text{ X } 10^{-6}\ kg$

$= 460\ kg$

Net biomass leaving the system per day = 2 MLD X 50 mg /l

$= 2 \text{ X } 10^6\ l/d \text{ X } 50\ mg/l$

$= 100 \text{ X } 10^6\ mg/d = 100\ Kg/d$

$$\theta_c = \frac{460\ kg}{100\ kg/day} = 4.6\ days$$

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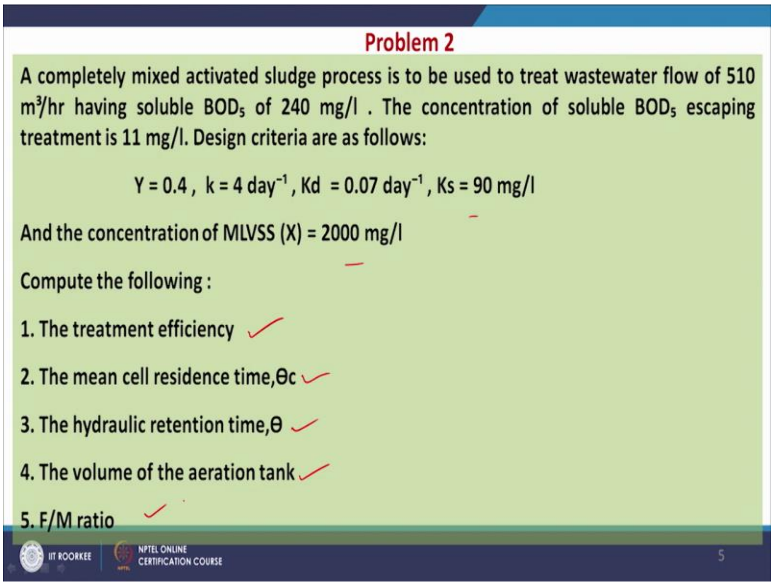

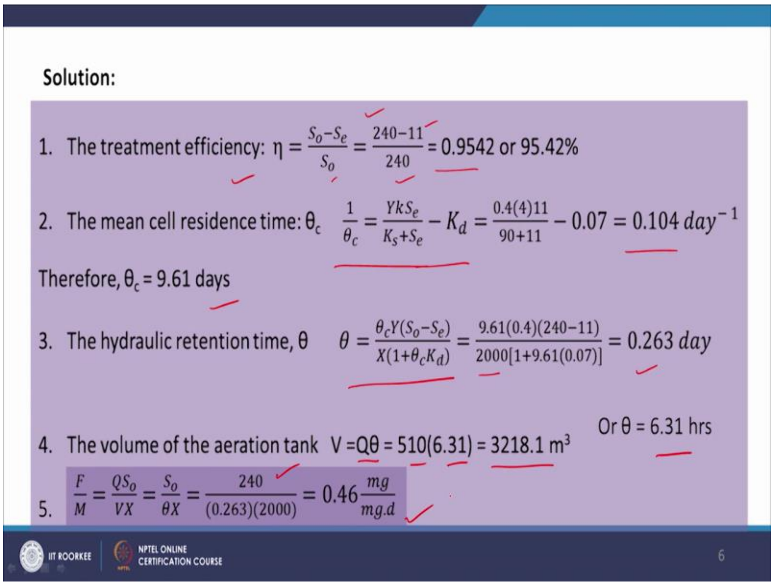

In problem number 2. Statement, A completely mixed activated sludge process used to be used to treat wastewater flow of 510-m^3/h having soluble BOD_5 of 240 mg/l, the concentration of soluble BOD_5 escaping treatment is 11 mg/l. Design criteria are as follows, Y = 0.4, k = 4 day^{-1}, Kd = 0.07 day^{-1}, Ks = 90 mg/l, and the concentration of MLVSS is equal to 2000 mg/l. So, these are given. So, we have to compute the following, the treatment efficiency, the mean cell residence time, the hydraulic retention time, the volume of the aeration tank, and feed by biomass ratio.

The treatment efficiency: $\eta = \frac{S_o - S_e}{S_o} = \frac{240 - 11}{240} = 0.9542 \text{ or } 95.42\%$

The mean cell residence time: θ_c $\quad \frac{1}{\theta_c} = \frac{YkS_e}{K_s+S_e} - K_d = \frac{0.4(4)11}{90+11} - 0.07 = 0.104\ day^{-1}$

Therefore, θ_c = 9.61 days

The hydraulic retention time, θ $\quad \theta = \frac{\theta_c Y(S_o - S_e)}{X(1+\theta_c K_d)} = \frac{9.61(0.4)(240-11)}{2000[1+9.61(0.07)]} = 0.263\ day$

Or ϴ = 6.31 hrs

The volume of the aeration tank V =Qθ = 510(6.31) = 3218.1 m^3

$$\frac{F}{M} = \frac{QS_o}{VX} = \frac{S_o}{\theta X} = \frac{240}{(0.263)(2000)} = 0.46 \frac{mg}{mg.d}$$

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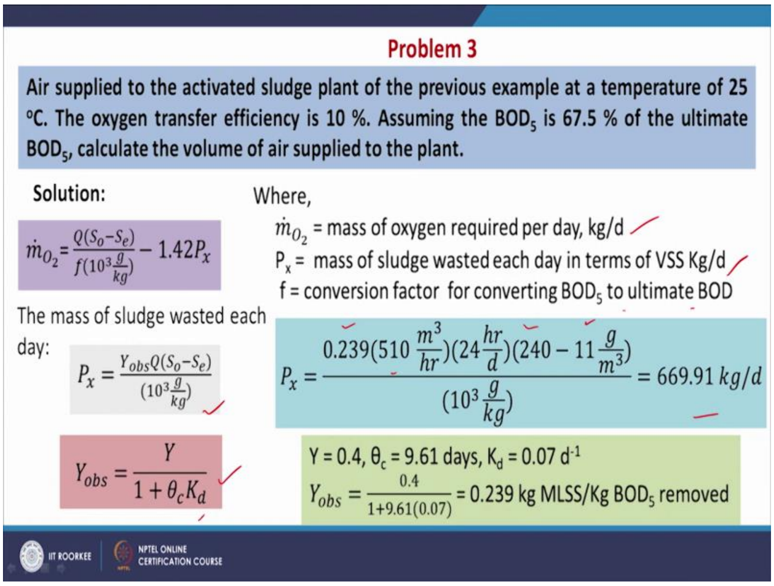

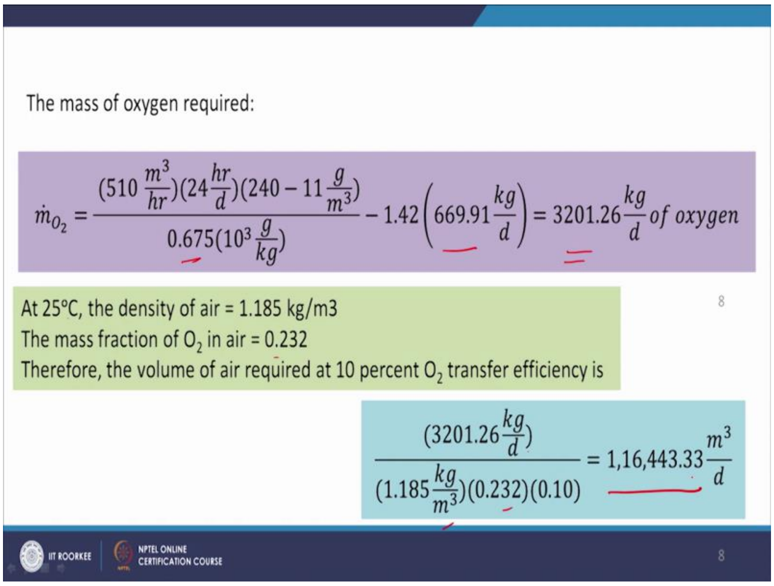

So, next problem number 3. Statement is air supplied to the activated sludge plant of the previous example at a temperature of 25 °C, the oxygen transfer efficiency is 10 %. Assume the BOD_5 is 67.5 % of the ultimate BOD_5, calculate the volume of air supplied to the plant. So, this is a problem of aeration basically, activated sludge process. So, how much here is required that we have to calculate.

And in this case, we have that formula,

$$\dot{m}_{O_2} = \frac{Q(S_o - S_e)}{f(10^3 \frac{g}{kg})} - 1.42 P_x$$

Where mO_2 is mass of oxygen required per day, kg per day, and P_x is the mass of sludge wasted each day in terms of VSS in kg per day. And f is the conversion factor for converting

BOD_5 to ultimate BOD, which is given in the statement that is equal to 67 % of the ultimate BOD_5. So, we will be using

$$P_x = \frac{Y_{obs} Q (S_0 - S_e)}{(10^3 \frac{g}{kg})}$$

$$Y_{obs} = \frac{Y}{1 + \theta_c K_d}$$

Y = 0.4, θ_c = 9.61 days, K_d = 0.07 d^{-1}

$$Y_{obs} = \frac{0.4}{1 + 9.61(0.07)} = 0.239 \text{ kg MLSS/Kg BOD}_5 \text{ removed}$$

$$P_x = \frac{0.239(510 \frac{m^3}{hr})(24 \frac{hr}{d})(240 - 11 \frac{g}{m^3})}{(10^3 \frac{g}{kg})} = 669.91 \text{ kg/d}$$

$$\dot{m}_{O_2} = \frac{(510 \frac{m^3}{hr})(24 \frac{hr}{d})(240 - 11 \frac{g}{m^3})}{0.675\,(10^3 \frac{g}{kg})} - 1.42\left(669.91 \frac{kg}{d}\right) = 3201.26 \frac{kg}{d} \text{ of oxygen}$$

At 25°C, the density of air = 1.185 kg/m3

The mass fraction of O_2 in air = 0.232

Therefore, the volume of air required at 10 % O_2 transfer efficiency is

$$= \frac{(3201.26 \frac{kg}{d})}{(1.185 \frac{kg}{m^3})(0.232)(0.10)} = 1{,}16{,}443.33 \frac{m^3}{d}$$

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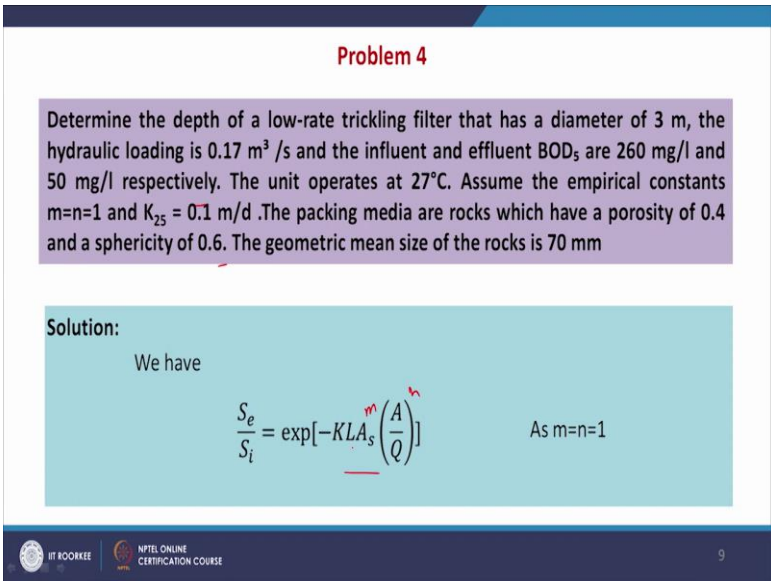

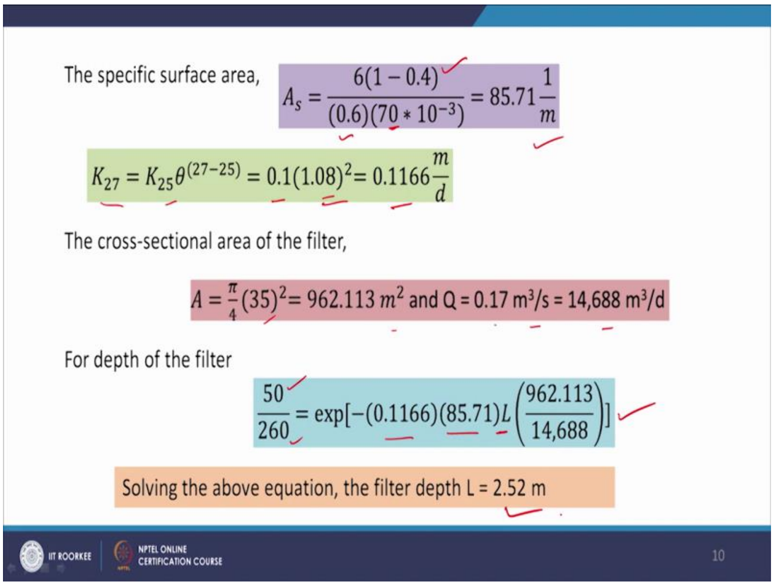

Now, problem number 4. Determine the depth of a low rate trickling filter that has a diameter of 3 m, the hydraulic loading is 0.17 m^3/s and the influent and effluent BOD_5 are 260 mg/l and 50 mg/l respectively. The unit operates at 27 ^oC, assume the empirical constants m = n = 1, and K 25 is equal to 0.1 m/d. The packing media are rocks which have a porosity of 0.4 and sphericity of 0.6. The geometric mean size of the rocks is 70 mm. So, similar type of problems we have discussed in our previous class also.

So, this is a problem related to trickling filters and you know that there is hardly any first principle-based models for the predictions of the performance of tickling filters. And we have discussed one empirical model as mentioned here

$\frac{S_e}{S_i} = \exp\left[-KLA_s\left(\frac{A}{Q}\right)\right]$ m= n =1

$A_s = \frac{6(1-0.4)}{(0.6)(70*10^{-3})} = 85.71\frac{1}{m}$

$K_{27} = K_{25}\theta^{(27-25)} = 0.1(1.08)^2 = 0.1166\frac{m}{d}$

$A = \frac{\pi}{4}(35)^2 = 962.113\ m^2$ and Q = 0.17 m^3/s = 14,688 m^3/d

$\frac{50}{260} = \exp\left[-(0.1166)(85.71)L\left(\frac{962.113}{14,688}\right)\right]$

Solving the above equation, the filter depth L = 2.52 m

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Problem 5

Determine the size of a high-rate trickling filter in which the sewage flow rate is 4 MLD with recirculation ratio 1.5 . The BOD of raw sewage is 260 mg/l from which 30 % BOD is removed in Primary settling tank (PST) and the desired BOD of the final effluent is 35 mg/l . (depth= 1.2 m)

Solution: We have to find the size of tricking filter, so we need to find the area and diameter of the filter

To find out the area we need to first calculate the volume

Using the formula ,

National Research Council, USA

$$E = \frac{100}{1 + 0.44\sqrt{\frac{W}{V * F}}}$$

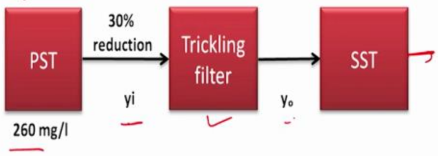
E= Efficiency

F = Recirculation factor

V = volume, m^3

W = organic load / BOD load in kg per day

Also, efficiency $E = \frac{\text{BOD of influent } (y_i) - \text{BOD of effluent } (y_o)}{\text{BOD of influent } (y_i)} * 100$



The BOD is reduced by 30 % before going into the trickling filter

y_i = 0.7 X 260

= 182 mg/l

y_o = 35 mg/l

$$E = \frac{182-35}{182} * 100 = 80.76$$

BOD load on filter in kg/d = 182 X 4 MLD

= 182 x 10^{-6} kg/l x 4 x 10^{6} l/d

= 728 kg/d

$$Recirculation\ factor\ (F) = \frac{1+R}{(1+0.1R)^2} = \frac{1+1.5}{(1+0.1*1.5)^2} = 1.89$$

$$E = \frac{100}{1 + 0.44\sqrt{\frac{728}{V * 1.89}}}$$

E= 80.76

V= 1314.06 m^3

$$Area = \frac{Volume}{Depth} = \frac{1314.06}{1.2} = 1095.05\ m^2$$

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

$1095 = \frac{\pi}{4}d^2$ d = 37.349 m

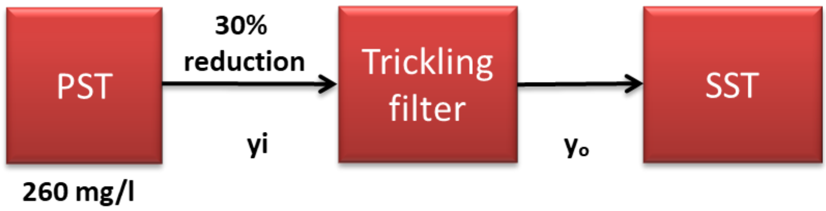
Next, problem number 5, the statement is determine the size of a high rate trickling filter in which the sewage flow rate is 4MLD with recirculation ratio of 1.5, the BOD of raw sewage is 260 mg/l, from which 30 % BOD is removed in primary settling tank, and the desired BOD of the final effluent is 35 mg/l. So, depth is equal to 1.2 m it is given. So, we have to determine the size of this high-rate trickling filter. So, this is again a problem related to trickling filter. And in the previous problem, we have used one empirical relationship.

Here, we are going to use another empirical relationship because the information which are provided those are not sufficient to use the previous empirical relationship. So, we will be using this empirical relationship here,

Using the formula, $E = \frac{100}{1+0.44\sqrt{\frac{W}{V*F}}}$

E= Efficiency, F = Recirculation factor, V = volume, m^3, W = organic load / BOD load in kg per day

Also, efficiency $E = \frac{\text{BOD of influent } (y_i) - \text{BOD of effluent } (y_o)}{\text{BOD of influent } (y_i)} * 100$



The BOD is reduced by 30 % before going into the trickling filter

$y_i = 0.7 \text{ X } 260$

$= 182 \text{ mg/l}$

$y_o = 35 \text{ mg/l}$

$E = \frac{182-35}{182} * 100 = 80.76$

BOD load on filter in kg/d = 182 x 4 MLD

$= 182 \times 10^{-6} \text{ kg/l} \times 4 \times 10^{6} \text{ l/d}$

$= 728 \text{ kg/d}$

Recirculation factor $(F) = \frac{1+R}{(1+0.1R)^2} = \frac{1+1.5}{(1+0.1*1.5)^2} = 1.89$

$E = \frac{100}{1+0.44\sqrt{\frac{728}{V*1.89}}}$

$$\text{Area} = \frac{\text{Volume}}{\text{Depth}} = \frac{1314.06}{1.2} = 1095.05\ m^2$$

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

$$1095 = \frac{\pi}{4} d^2$$

d = 37.349

So, the depth is given, diameter is calculated. So, the dimension of the trickling filter we are able to find out.

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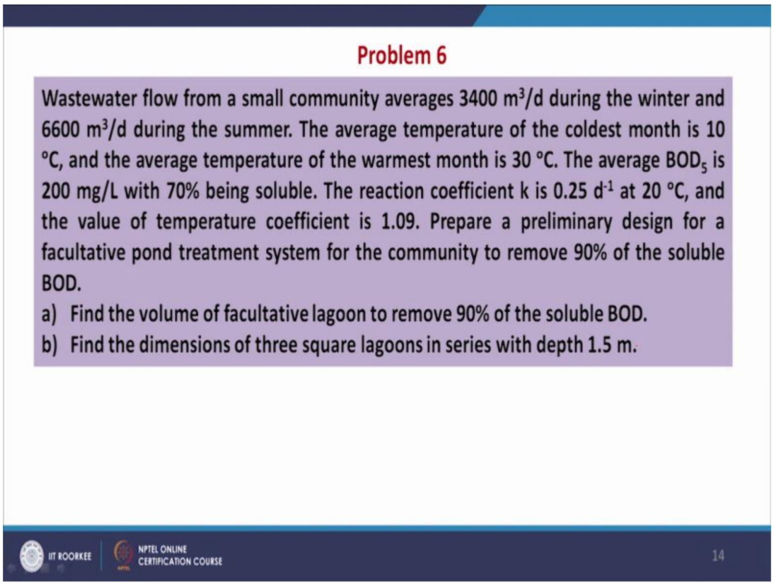
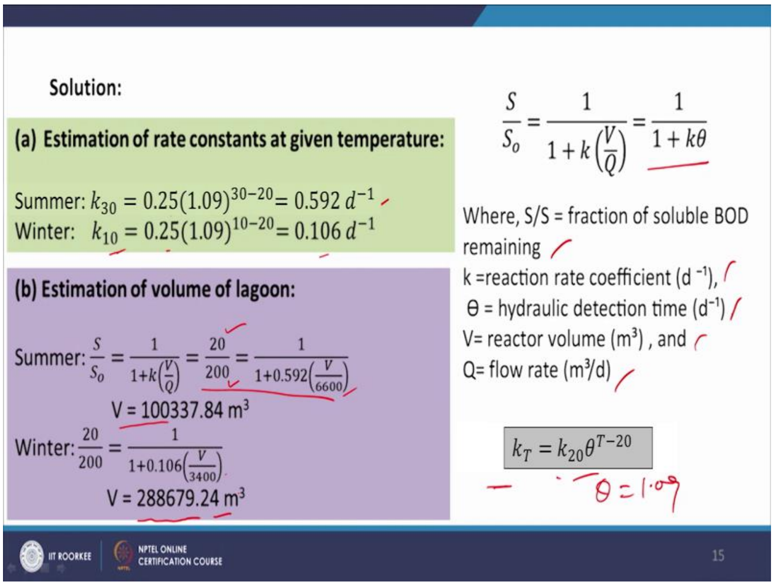
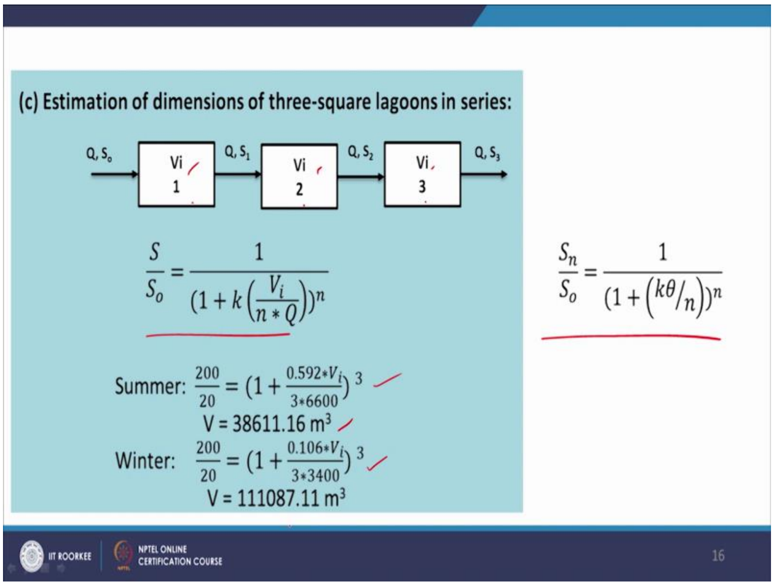






Next, problem number 6. Wastewater flow from a small community averages 3400 m^3/d during the winter, and 6600 m/d during the summer. The average temperature of the coldest month is 10 ^{o}C, and the average temperature of the warmest month is 30 ^{o}C. The average BOD 5 is 200 mg/l with 70 % being soluble. The reaction coefficient k is 0.25 per day at 20 ^{o}C, and the value of temperature coefficient is 1.09. Prepare a preliminary design for a facultative pond treatment system for the community to remove 90 % of the soluble BOD.

We have to make some preliminary design and how to calculate find the volume of the facultative lagoon to remove 90 % of the soluble BOD, and find the dimensions of three square lagoons in series with depth 1.5 m. So, two parts, the first part we have to calculate the volume of the facultative lagoon. And then second part we have to calculate the dimension of the three square lagoons in series with depth to 1.5 m. So, in place of the one big lagoon, if we use three equal volume lagoon with the same capacity, then what will be the dimensions of these lagoons that we have to calculate.

So, there are two part of this problem. So, now, how we can solve it? We have some design expressions we have discussed in our previous class for lagoon system,

Estimation of rate constants at given temperature:

Summer: $k_{25} = 0.25(1.09)^{30-20} = 0.592\ d^{-1}$

Winter: $k_{10} = 0.25(1.09)^{10-20} = 0.106\ d^{-1}$

Estimation of volume of lagoon:

$$\frac{S}{S_o} = \frac{1}{1+k\left(\frac{V}{Q}\right)} = \frac{1}{1+k\theta}$$

Where, S/So = fraction of soluble BOD remaining

k =reaction rate coefficient (d^{-1}),

ϴ = hydraulic detection time (d^{-1}),

V= reactor volume (m^3),

Q= flow rate (m^3/d)

$k_T = k_{20}\theta^{T-20}$

ϴ =1.09

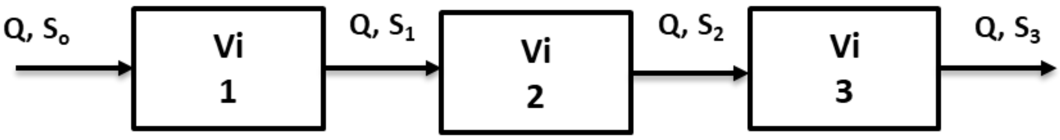
Summer: $\frac{S}{S_o} = \frac{1}{1+k\left(\frac{V}{Q}\right)} = \frac{20}{200} = \frac{1}{1+0.592\left(\frac{V}{6600}\right)}$

V = 100337.84 m^3

Winter: $\frac{20}{200} = \frac{1}{1+0.106\left(\frac{V}{3400}\right)}$

V = 288679.24 m^3

Estimation of dimensions of three-square lagoons in series:



$\frac{S_n}{S_o} = \frac{1}{(1+\left(k\theta/n\right))^n}$

$\frac{S}{S_o} = \frac{1}{(1+k\left(\frac{V_i}{n*Q}\right))^n}$

Summer: $\frac{200}{20} = \left(1 + \frac{0.592*V_i}{3*6600}\right)^3$

V = 38611.16 m^3

Winter: $\frac{200}{20} = \left(1 + \frac{0.106*V_i}{3*3400}\right)^3$

V = 111087.11 m^3

So, now, the second part is completed. Up to this in this class. Thank you very much for your presence.