SANITARY TUTORIAL'S SOLUTION

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Tutorial 4, 5, 6, 7

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TUTORIAL 4 (Related to Chapter 6)

31. The treated domestic sewage of a town is to be discharged in a strea[m]. Determine the maximum permissible effluent BOD and the percenta[ge] purification required in the treatment plant with the followi[ng] particulars:

Population of town = 40000;
Minimum flow of stream = 0.15 m^3/s;
BOD of stream = 2 mg/l;
DWF of sewage = 150 lpcd;
BOD contribution per capita = 0.075 kg/day;
Maximum BOD of stream on downstream = 5 mg/l.

[Ans: 11.52 mg/l, 97.7%

32. A stream having a flow of 1 m^3/s and BOD 4 mg/l is saturated wit[h] DO.It receives an effluent discharge of 0.25 m^3/s having BOD of 20 mg/l and DO of 4 mg/l. If the average velocity of flow is 0.15 m/s, calculate the DO deficit at points 20 KM and 40 KM downstream. Assume that the temperature is 20°C throughout and BOD is measured at 5 days. Take rate constants for effluent and stream as 0.12 and 0.30/day respectively, and saturation DO at 20°C as 9.17 mg/l.

[Ans: 2.34 mg/l, 2.09 mg/l]

33. A town discharges 120 cumec of sewage into the river having rate of flow of 1600 cumec during lean period with a velocity of 0.1 m/s. The 5-day BOD of sewage at the given temperature is 250mg/l. Find the amount of critical DO deficit, and when and where it will occur in the downstream portion of river. Assume deoxygenation coefficient K as 0.1/day and coefficient of self purification f_s as 3.5. Saturation DO at given temperature is 9.2 mg/l.

[Assuming DO of sewage = 0 and BOD of river water = 0, Ans: 4.532 mg/l, 2.064 days, 17.833KM]

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34. An industry is proposed to establish near the river. The characteristics of raw sewage and the characteristics of river in which the sewage is discharged are as follows:

i. Sewage discharge of a town = $1.72\ m^3/s$;
ii. Minimum river discharge = $7.24\ m^3/s$
iii. Temperature of the sewage = 30.5°C
iv. Temperature of the river water = 17.5°C
v. Deoxygenation constant = 0.1/day at 20°C
vi. Reoxygenation constant = 0.5/day at 20°C
vii. BOD_5 at 20°C of sewage = 225 mg/l
viii. BOD_5 at 20°C of river water = 1.2 mg/l
ix. DO in sewage = 0
x. DO in river water = 90% of saturation value
xi. Saturation DO of water at 20°C = 9.17 mg/l
xii. Saturation DO of water at 17.5°C = 9.64 mg/l
xiii. Minimum DO to be maintained in the river = 4.4 mg/l

Does it is necessary to treat or not. Calculate the allowable BOD_5 in the sewage that can be discharged in the river. What will be the degree of sewage treatment required? *[Ans: Treatment is necessary, 112.68 mg/l, 50%]*

35. 125 cumec of sewage of a city is discharged in a perennial river which is fully saturated with oxygen and flows at a rate of 1600 cumec with a minimum velocity of 0.12 m/s. If the 5-day BOD of the sewage is 300 mg/l, find out where the critical DO will occur in the river. Assume: coefficient of purification of river as 4.0, coefficient of DO as 0.11/day and the ultimate BOD as 125% of the 5-day BOD of the mixture of sewage and river water. Also find the critical deficit.

[Assuming temperature of river water is 20°C and DO content of sewage is zero.
Ans: 17.874 KM below outfall, 4.391 mg/l]

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36. Using the following data, find out the DO at the end of 2 days:

S. No.	Parameters	For River	For Wastewater
1	Flow (m^3/s)	20	2
2	DO (mg/l)	9	0
3	BOD (mg/l)	3	200

Assume, K = 0.12/day and R = 0.4/day *[Ans: 3.88 mg/l]*

37. A town discharges 0.06 m^3/s of sewage with a 5-day BOD of 180 mg/l into a river having flow and 5-day BOD as 0.6 m^3/s and 6 mg/l respectively. The temperature of the river water and effluent is same i.e., 20°C. The rate constants K and R are found to be 0.1 and 0.3 per day respectively The DO contents of the effluent and river water are 2.1 mg/l and 8.2 mg/l respectively prior to mixing. The saturation DO of river water at 20°C is 9.17 mg/l. Calculate the magnitude of the critical DO deficit and the time at which it occurs. *[Ans: 6.45 mg/l, 2.17 days]*

38. The population of town is 50000 and the domestic sewage is 160 lpcd. The per capita BOD is 80 gm/day. The diary waste of the town is 2.4×10^6 liters/day with BOD of 1600 mg/l and the waste from other industries is 1.6×10^6 liters/day with BOD of 2000 mg/l. DO of both industrial and domestic sewage is zero. In the design of sewage system 15% overall expansion is to be kept in design. The sewage is discharged in the natural river having minimum discharge of 7000 liters/sec with a saturation DO content of 9 mg/l and BOD of zero. The dissolve oxygen content in the river to be maintained is 4 mg/l. Determine the degree of treatment required to the sewage. Assume saturation DO in the river after mixing waste is equals to DO content of river before mixing. Assume other data suitably. *[Assuming R = 0.1/day and R = 0.3/da, Ans: 10.41%]*

39. A wastewater effluent of 575 l/s with BOD = 80 mg/l, DO = 3 mg/l and temperature of 20°C enters a river where the flow is 3.5 m^3/s and BOD = 5 mg/l, DO = 7.8 mg/l and temperature of 20°C. From laboratory BOD testing, Deoxygenation constant for the waste is 0.09/day at 20°C.

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The river downstream has an average velocity of 0.2 m/s and depth of flow is 1.4 m. Calculate the degree of treatment required for the wastewater effluent if minimum DO to be maintained in the river is 4.0 mg/l. ***[Assuming bed activity constant as 0.1, Ans: No treatment required]***

40. A wastewater treatment plant disposes off its effluents into a stream at a point A. Characteristics of the stream at a location fairly upstream of A and of the effluent are as below:

Item	Effluent	Stream
Flow (m^3/s)	0.16	0.4
DO (mg/l)	1.60	8.20
Temperature (°C)	25	22
BOD at 20°C (mg/l)	32	2.0

Assume that the deoxygenation constant K' at 20°C (base e) = 0.20/day and reoxygenation constant R' at 20°C (base e) = 0.40/day for the mixture. Equilibrium concentration of dissolved oxygen for fresh water is as follows:

Temperature (°C)	18	20	22	23	24	25	26
DO (mg/l)	9.54	9.17	8.99	8.83	8.53	8.38	8.22

The velocity of the stream downstream of the point A is 0.16 m/ss. Determine the critical oxygen deficit and its location. Use temperature coefficients of 1.04 for K' and 1.02 for R'.

[Ans: 5.1 mg/l, 34.09 Km from outfall]

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TUTORIAL 5 (Related to Chapter 7)

41. Design a rectangular grit chamber from the following data:

    Maximum flow of sewage = 55×10^6 lit/d;
    Specific gravity of grit = 2.7;
    Size of grit particles to be removed = 0.21 mm;
    Assume temperature 'T' = 20°C

42. Design a rectangular grit chamber from the following data:

    Maximum flow of sewage = 30×10^6 lit/d;
    SOR = 0.03 m/s;
    Detention time = 1 min.

    If the specific gravity of grit and organic particles are 2.7 and 1.2 respectively, check the acceptability of flow velocity in the chamber. Use Camp-Shield equation with K = 0.06 and f = 0.03 and the particle diameter of 0.21 mm for both grit and organic solids.

43. Design a grit chamber for a maximum discharge 8000 m^3/d to remove the particles up to 0.2 mm diameter having specific gravity of 2.65, settling velocity 'v_s' ranges from 0.018 – 0.022 m/s. Maintain a constant flow through a velocity of 0.3 m/s through the provision of flow weir.

44. Design a circular sewage sedimentation tank for a town having population of 40000. The average water demand is 140 lpcd. Assume that 70% water reaches at treatment plant and maximum demand is 2.7 times average demand. Also check surface loading. What will be the dimension of tank if it is rectangular?

45. Calculate the effluent BOD of a two stage trickling filter with the following data:

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Sewage flow = 4MLD;
Influent BOD in first TF = 250 mg/l;
Volume of first filter = 600 m^3;
Volume of second filter = 400 m^3 and
Recirculation ratio for both filters = 1.5. *[Ans: 35.31 mg/l]*

46. A municipal wastewater having a BOD of 200 mg/l is to be treated by a two stage trickling filter. The designed effluent quality is 25 mg/l of BOD. If both of the filters depth to be 1.8 m and recirculation ratio 2:1, find the required filter diameters for the condition that Q = 7560 m3/day; efficiency of first stage TF = efficiency of second stage TF and PST removes 35% of BOD. *[Ans: 10.3 m ; 15.5 m]*

47. Calculate the size of a secondary filter of two stage trickling filter treating sewage of 2 MLD at a recirculation ratio of 2:1. The BOD_5 of the influent sewage to first filter is 170 mg/l and final effluent BOD_5 should be less than 30 mg/l. Efficiency of first stage filter is 70%. Assume organic loading of filter as 8000 kg BOD_5/ha-m/day. *[Assuming d = 1.5 m, Ans: 7.2 m]*

48. Design an oxidation pond for treating domestic sewage from a community having 10000 populations. The average sewage flow is 200 lpcd and BOD of sewage is 300 mg/l. Assume the organic loading as 300 kg BOD/ha/day.

49. Design an oxidation pond to treat 5000 m^3/s of domestic sewage which has a BOD_5 of 500 mg/l. Assume acceptable BOD_5 loading = 250 kg/ha/day and depth = 1 m.

50. An average operating data for conventional activated sludge treatment plant is as follows:

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1. Wastewater flow : 50000 m^3/d
2. Volume of Aeration tank : 15500 m^3
3. Influent BOD : 200 mg/l
4. Effluent BOD : 25 mg/l
5. Mixed liquor suspended solids (MLSS) : 3000 mg/l
6. Effluent suspended solids : 40 mg/l
7. Waste solid suspended solids : 120000 mg/l
8. Quantity of waste sludge : 250 m^3/d

Based upon above, determine:

(a) Aeration period (hrs)

(b) Food to micro-organisms ratio (F/M) (kg BOD per day / kg MLVSS)

(c) Percentage efficiency of BOD removal

(d) Sludge age (days)

[Assuming MLVSS/MLSS = 0.8. Ans: 7.44 hrs; 0.269/day; 87.5%; 9.32 days]

51. Design a activated sludge unit treatment for a town with the following data:

Population = 65000; Average sewage flow = 210 lpcd;

BOD of raw sewage = 210 mg/l;

BOD removal in primary treatment = 40%;

Overall BOD removal required = 90%

TUTORIAL 6 (Related to Chapter 8)

52. The moisture content of sludge is reduced from 95% to 90% in a sludge digestion tank. Find the % decrease in the volume of sludge. *[Ans: 50%]*

53. A trickling filter plant treats 1500 m^3 of sewage /day with a BOD_5 of 230 mg/l and SS of 250 mg/l. Estimate the total solids production assuming that primary clarification removes 30% of BOD and 55% of influent solids. *[Ans: 327 Kg/day]*

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59. Design a rectangular grit chamber from the following data:
Maximum flow of sewage = 55×10^6 lit/d;
Specific gravity of grit = 2.7;
Size of grit particles to be removed = 0.21 mm;
Assume temperature 'T' = 20°C

60. Design a rectangular grit chamber from the following data:

Maximum flow of sewage = 30×10^6 lit/d;
SOR = 0.03 m/s;
Detention time = 1 min.

If the specific gravity of grit and organic particles are 2.7 and 1.2 respectively, check the acceptability of flow velocity in the chamber. Use Camp-Shield equation with K = 0.06 and f = 0.03 and the particle diameter of 0.21 mm for both grit and organic solids.

TUTORIAL 7 (Related to Chapter 9)

61. Design a double pit VIP latrine for a family of 10 users. Assume the necessary data.

62. Design a septic tank for a small colony of 100 users with average daily sewage flow 135 liters per head per day. Assume the necessary data suitably. Also design the dispersion trench, if the infiltration rate of soil is 20 min/cm.

63. Design the septic tank and the soak pit for 20 users. Assume the rate of the wastewater as 80 lpcd. The detention time in the septic is 24 hours and the sludge is cleaned in every 3 years. The absorption value of the soil is 100 liters/m^2/day.

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Tutorial 4. (Related to Chapter 6).

1. Solution;

Given;

(P) Population of town = 40000

(Q_r) Minimum flow of stream = $0.15 m^3/sec$.

(BOD_r) BOD of stream = $2 mg/l$.

DWF of stream = ~~day~~ 150lpcd.

BOD contribution per capita = 0.075kg/day.

Maximum BOD of stream on downstream = $5 mg/l$.

To find; Maximum permissible effluent BOD = ?

% purification required = ?

Quantity of sewage (Q_s) = ~~PR~~ X DWF

$= \cancel{2} \times 150 \times 40000$.

$= \cancel{0.1388 m^3/sec} = 0.069 m^3/sec$.

~~BOD sewage = 0.075~~

Now;

$$Q_s C_s + Q_R C_R = C_{min} Q_{total}$$

or, $0.069 \times C_s + 0.15 \times 2 = 5 \times (0.069 + 0.15)$

$\therefore C_s = 11.52 mg/lit$.

$\therefore$ Permissible BOD = 11.52 mg/lit.

Actual BOD = 0.075kg/day/capita

$= \dfrac{0.075 \times 10^6}{150}$

$= 500 mg/lit$.

$\therefore$ % purification required = $\dfrac{\text{Actual} - \text{Permissible}}{\text{Actual}}$

$= \dfrac{500 - 11.52}{500}$

$= 97.69\%$

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$DO = 9.2 - 8.558 = 0.642 \, mg/lit.$

$BOD_{min} = Y_s = L_o(1 - 10^{-kt})$

or, $17.44 = L_o(1 - 10^{-0.1 \times 5})$

$\therefore L_o = 25.50 \, mg/lit.$

Now;

(i) $t_c = \frac{1}{k(f_s - 1)} \log_{10}\left[f_s\left(1 - (f_s - 1)\frac{D_o}{L_o}\right)\right]$

$= \frac{1}{0.1(3.5-1)} \log_{10}\left[3.5\left(1 - (3.5-1) \times \frac{0.642}{25.50}\right)\right]$

$= 2.063 \, day$

ii) $D_c = \frac{1}{f_s} L_o 10^{-kt_c}$

$= \frac{1}{3.5} \times 25.50 \times 10^{-0.1 \times 2.063}$

$= 4.530 \, mg/lit.$

iii) $X_c = Vt_c$

$= 0.1 \times 2.063 \times 24 \times 3600$

$= 17.82 \, km.$

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Solution;

Given;

$Q_{sewage} (Q_s) = 1.72 m^3/sec.$

$Q_{river} (Q_r) = 7.24 m^3/sec.$

Tempr of sewage $(T_s) = 30.5°c$

Tempr of river $(T_r) = 17.5°c.$

Deoxygenation constant $(K) = 0.1/day$

Reoxygenation constant $(R) = 0.5/day.$

$BOD_S = 225 mg/lit$

$BOD_r = 1.2 mg/lit$

$DO_S = 0$

$DO_r = 90\%$ of saturation level.

Saturation DO $= 9.17 mg/l.$

Then; Saturation DO of riverwater $= 9.64 mg/l.$

1) $DO_{min} = \frac{DO_S \times Q_s + DO_r \times Q_r}{Q_s + Q_r} = \frac{0 \times 1.72 + 90\% \times 9.\cancel{64} \times 7.24}{1.72 + 7.24}$

$= 7.014 mg/lit.$

2) Initial DO deficit $(D_0) = 9.17 - 7.014$

$= 2.16 mg/l.$

3) $BOD (min) = \frac{BOD_S \times Q_s + BOD_r \times Q_r}{Q_s + Q_r}$

$= \frac{225 \times 1.72 + 1.2 \times 7.24}{1.72 + 7.24}$

$= 44.16 mg/lit.$

4) Critical DO deficit.

$D_c = DO_{sat} - DO_{min}$

$= 9.17 - 4.4$

$= 4.77 mg/lit.$

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We have

$$f_s = \frac{R}{K} = \frac{0.5}{0.1} = 5.$$

Then; $$\left(\frac{L_0}{f_s D_c}\right)^{f_s - 1} = f_s\left[1 - (f_s - 1)\frac{D_0}{L_0}\right]$$

or, $$\left(\frac{L_0}{5 \times 4.77}\right)^4 = 5\left(1 - 4 \times \frac{2.16}{L_0}\right)$$

Solving for L_0 we get;

$$L_0 = 33.063 \text{mg/l}.$$

6) Max. allowable BOD_5 of mix

$$(BOD_5)_{allowable, mix} = L_0(1 - 10^{-kt}) \text{ at } 20°C$$
$$= 33.063(1 - 10^{-0.1 \times 5})$$
$$= 22.607 \text{mg/lit}$$

$$(BOD_5)_{allowable\ mix} = \frac{(BOD)_{Sewage\ allowable} \times Q_s + BOD_r \times Q_r}{Q_s + Q_r}$$

$$22.607 = \frac{(BOD)_{s\ allowable} \times 1.72 + 1.2 \times 7.24}{1.72 + 7.24}$$

$$(BOD_{sewage})_{allow.} = 112.71 \text{mg/lit}.$$

Here $BOD_s > BOD_{s\ allowable}$.

So treatment is required.

8) Degree of treatment

$$p = \frac{BOD_s - (BOD_s)_{allow}}{BOD_s} \times 100\%$$

$$= \frac{225 - 112.71}{225} \times 100 = 49.90 \simeq 50\%$$

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Solution:

S.No.	Parameters	For river	For wastewater.
1	Flow(m^3/sec)	20	2
2	DO(mg/lit)	9	0
3	BOD (mg/lit)	3	200.

Assume $k = 0.12$/day & $R = 0.4$/day

Given; $Q_r = 20\,m^3/sec$ $\quad Q_s = 2\,m^3/sec.$

$DO_r = 9\,mg/lit \quad DO_s = 0\,mg/L$

$BOD_r = 3\,mg/lit \quad DO_s = 200\,mg/L$

DO at the end of 2 day (DO_2) = ?

1) $DO_{mix} = \dfrac{20 \times 9 + 2 \times 0}{22} = 8.18\,mg/lit.$

2) Initial DO deficit (D_o) $= 9 - 8.18 = 0.82\,mg/lit$

3) $BOD_{mix} = \dfrac{3 \times 20 + 200 \times 2}{22} = 20.91\,mg/l.$

4) Ultimate BOD; $BOD_{mix} = L_o(1 - 10^{-kt})$

or, $L_o = \dfrac{20.91}{1 - 10^{-0.12 \times 5}} = 27.92\,mg/lit$

5) For $t = 2$ days.

$$DO_t = \frac{kL_o}{R-k}\left[10^{-kt} - 10^{-Rt}\right] + D_o 10^{-Rt}$$

$$DO_2 = \frac{0.12 \times 27.92}{0.4 - 0.12}\left[10^{-0.12 \times 2} - 10^{-0.4 \times 2}\right] + 0.82 \times 10^{-0.4 \times 2}$$

$\therefore DO_2 = 5.12\,mg/lit$

Now, At the end of 2 days

$(DO_2)_{end} = 9 - 5.12$

$= 3.88\,mg/lit$ Ans.

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(37) Solution;

Given, $Q_s = 0.06 m^3/sec.$

$BOD_s = 180 mg/lit.$

$Q_r = 0.6 m^3/sec$

$BOD_r = 6 mg/lit.$

$DO_s = 2.1 mg/lit$

$DO_r = 8.2 mg/lit$

Saturation DO of river = 9.17 mg

Temp^r of river & effluent = 20°C.

$k = 0.1/day$

$R = 0.3/day.$

To find; Magnitude of critical DO deficit = ?

Time at which it occurs = ?

Then;

1) $DO_{min} = \cancel{0.06 \times 180 + 0.6 \times 6}\ \dfrac{2.1 \times 0.06 + 8.2 \times 0.6}{0.6 + 0.06} = 7.65 mg/l$

Initial DO deficit $(D_0) = DO_{sat} - DO_{min}$

$= 9.17 - 7.65$

$= 1.52 mg/lit.$

2) $BOD_{min} = \dfrac{BOD_s \times Q_s + BOD_r \times Q_r}{Q_s + Q_r} = 21.82 mg/lit.$

3) $BOD_{min} = L_0(1 - 10^{-kt})$

$\therefore L_0 = \dfrac{21.82}{1 - 10^{-0.1 \times 5}} = 31.91 mg/l.$

4) $t_c = \dfrac{1}{k(f_s - 1)} \log_{10}\left[f_s\left(1 - (f_s - 1)\dfrac{D_0}{L_0}\right)\right]$

$= \dfrac{1}{0.1 \times 2} \log_{10}\left[3 - \left(1 - 2 \times \dfrac{1.52}{31.91}\right)\right]$

$= 2.17 days.$

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We have;

Critical DO deficit amounts

$$D_c = \frac{L_0}{f_s} 10^{-k t_c}$$

$$= \frac{31.91}{3} \times 10^{-0.1 \times 2.17}$$

$$\therefore D_c = 6.45 mg/lit$$

(40) Solution

Given;

k' at 20°C (base e) = 0.20/day.

$\therefore$ k at 20°C (base 10) = $\frac{0.20}{2.303}$ = 0.087/day

R' at 20°C (base e) = 0.40/day

R at 20°C (base 10) = 0.174/day

Q_s = 0.16 m³/sec DO_s = 1.60 mg/l Tempr = 25°C BOD_s = 32 mg/l

Q_r = 0.4 m³/sec DO_r = 8.20 mg/l Tempr = 22°C BOD_r = 2.0 mg/lit.

Then;

$$DO_{min} = \frac{0.16 \times 1.60 + 0.4 \times 8.20}{0.4 + 0.16} = 6.314 mg/lit$$

BOD_5 of the mixture

$$(BOD)_{mix} = \frac{0.16 \times 32 + 0.4 \times 2}{0.16 + 0.4} = 10.571 mg/l.$$

Similarly

$$T_{min} = \frac{25 \times 0.16 + 22 \times 0.4}{0.16 + 0.4} = 22.86°C.$$

$$BOD_{min} = L_0 (1 - 10^{-kt})$$

$$\therefore L_0 = \frac{10.571}{1 - 10^{-0.087 \times 5}} = 16.71 mg/lit$$

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Saturation DO of the mix at 22.86°C.

$(DO)_{sat} = 8.701\,mg/l$.

Initial DO deficit $= 8.701 - 6.314$

$= 2.387\,mg/lit$

$K_T = K_{20}\theta^{(T-20)}$

$K_{22.86} = 0.087 \times (1.04)^{22.86-20}$

$K_{22.86} = 0.097/day$

Similarly $R_{22.86} = 0.174(1.02)^{2.86} = 0.184/day$.

i) $t_c = \frac{1}{K(f_s - 1)} \log_{10}\left[f_s\left[1-(f_s-1)\frac{D_0}{L_0}\right]\right]$

$= \frac{1}{0.097 \times (2-1)} \log_{10}\left[2\left(1 - 1 \times \frac{2.387}{16.71}\right)\right]$

$= 2.41\,days$

ii) $x_c = V \times t_c$

$= 0.16 \times (2.41 \times 24 \times 60 \times 60)$

$= 33.3\,KM$.

iii) Critical deficit.

$D_c = \frac{L_0}{f_s} 10^{-Kt_c}$

$= \frac{16.71}{1.897}\, 10^{-0.097 \times 2.41}$

$= 5.02\,mg/l$ Ans.

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Tutorial 5

42. Solution;

Given; Max^m flow of sewage (Q) = 30×10^6 l/day = 0.347 m^3/sec.

(V_s) SOR = 0.03 m/s

Detention time = 1 min. = 60 sec

Sp. gravity of grit ~~particles~~ = 2.7

" " " organic particles = 1.2.

K = 0.06, f = 0.03

diameter of particle = 0.21 mm.

Then;

$$V_s = \frac{Q}{A_s} = \frac{0.347}{0.03} = A_s$$

$$\therefore A_s = 11.57 \text{ m}^2$$

Capacity of grit chamber (V) = Q × t = 0.347 × 60

= 20.82 m^3

$$\text{Effective depth} = \frac{V}{A} = \frac{20.82}{11.57} = 1.799 \simeq 1.8 \text{ m.}$$

Assuming width (B) = 1 m

$$\text{length of grit chamber (L)} = \frac{A_s}{B} = \frac{11.57}{1} = 11.6 \text{ m.}$$

check for horizontal velocity

$$V_h = \frac{L}{t} = \frac{11.6}{60} = 0.192 \text{ m/s.}$$

Now,

$$V_{co} = \sqrt{\frac{8k}{f}(s-1)gd_o} = \sqrt{\frac{8 \times 0.06}{0.03}(1.2-1) \times 9810 \times 0.21}$$

$$= 0.08 \text{ m/s.}$$

$$V_{cg} = \sqrt{\frac{8k}{f}(s_g-1)gd_g} = \sqrt{\frac{8 \times 0.06}{0.03}(2.7-1)\, 9810 \times 0.21}$$

$$= 0.237 \text{ m/s.}$$

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Here $V_{co} < V_h < V_{cg}$. OK.

Provide $FB = 0.2m$.

Overall depth $(D) = 1.8 + 0.2 = 2m$.

Provide a grit chamber $(11.6 \times 1 \times 2.0)$ long, wide & depth.

(43) solution

Given; $Q = 8000 m^3/day = 0.0926 m^3/sec$.

$d = 0.2mm$

$S = 2.65$

$V_s = (0.0182 - 0.022) m/s$.

Adopt $V_s = 0.02 m/s$

$V_h = 0.3 m/s$.

Then; Critical velocity for removing grit

$$V_{cg} = 4\sqrt{g (S_g - 1) d_g}$$

$$= 4\sqrt{9810(2.65-1) \times 0.2}$$

$V_{cg} = 0.227 m/sec$

Here $V_{cg} < V_h$

Hence grit is not settled. but carried out

So Assume $V_h = 0.2 m/sec$ (Safe)

Also, detention time $(t) = 60 sec$.

Length of grit chamber $(L) = V_h \times t = 0.2 \times 60 = 12M$ (10 to 17

$$A_s = \frac{Q}{V_s} = \frac{0.0926}{0.02} = 4.63 m^2$$

$L \times B = A_s = 4.63$

$$B = \frac{4.63}{12} = 0.386 m \simeq .4m.$$

Capacity of grit chamber $(V) = Q \times t$

$= 0.0926 \times 60$

$= 5.556 M^3$.

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Eff depth (d) = $\frac{V}{A} = \frac{5.556}{4.63} = 1.2m$.

Providing freeboard (FB) = 0.3m

Overall depth (d) = 1.2 + 0.3 = 1.5m.

Hence, provide 12m long, 0.4m wide & 1.5m depth of tank.

(44) soln;

Given;

Popn = 40,000.

Water demand = 140 l/day/pop

Then;

Average sewage flow = 140 × 40,000 × 0.70

= 3.92×10^6 l/day

Peak or maxm sewage flow = $2.7 \times 3.92 \times 10^6$ = 0.1225 m^3/sec.

Assume

detention time (t) = 1 hrs = 3600 sec.

Volume of tank = Q × t = 0.1225 × 3600 = 441 m3.

Assume.

Effective depth (d) = 3m.

Surface Area (A) = $\frac{V}{d} = \frac{441}{3}$ = 147.0 m2.

For circular tank;

Check Surface loading;

$SOR = \frac{Q}{As} = \frac{0.1225}{147} = 72 m^3/m^2/day > (40 to 50\ m^3/m^2/da$

So change depth.

Assume depth (d) = 2 m

$A_s = \frac{441}{2} = 220.5 m^2$

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5) Solution;

Given $Q = 4.5 \times 10^6$ lit/day

$SS = 275$ mg/lit.

Wt of solid removes = 50% of 275 = 137.5 mg/lit.

$= 137.5 \times 4.5 \times 10^6 \times 10^{-6}$ kg/day

$(W_s) = 618.75$ kg/day.

(a) $m = 98\%$.

$P_s = 100 - 98 = 2\%$.

$P_s = \frac{W_s}{W_{s1}} \times 100\%$ $\Rightarrow W_{s1} = \frac{618.75}{2} \times 100 = 30937.5$ kg/day

$\therefore V_{s1} = \frac{W_{s1}}{S_{s1} \times \gamma_w} = \frac{30937.5}{1.02 \times 1000} = 30.33 m^3$ //.

56) Solution

Volume of freshsludge from PST & TF $(V_{s1}) = 81.1 m^3$

Initially, Moisture content $(m_1) = 95\%$

Finally, moisture content $(m_2) = 87\%$

Final volume of sludge $(V_f) = ?$

Then;

$m_1 = 95\%$. $\therefore P_{s_1} = 5\%$.

$m_2 = 87\%$. $P_{s_2} = 13\%$

Then;

$$P_{s_1} \times V_{s_1} = P_{s_2} \times V_{s_2}$$

or, $5 \times 81.1 = 13 \times V_{s1_2}$

$\therefore (V_{s1})_2 = 31.192 m^3$

$\therefore$ finally the volume of sludge = $31.192 m^3$

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(57) Solution;

Given; Volume of fresh sludge (V_f) = 81.1 m^3

Volume of digested sludge (V_d) = 31.192 m^3

Detention time = 30 days.

Assume proggress of digestion is parabolic & no monsoon st

$$V = \left[V_f - \frac{2}{3}(V_f - V_d)\right] T_d + V_d T_m$$

$$= \left[81.1 - \frac{2}{3}(81.1 - 31.192)\right] \times 30$$

$$= 1434.84 m^3.$$

Assume effective depth = 6m.

Surface area of tank (A) = $\frac{V}{d} = \frac{1434.84}{6} = 239.14 m$

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

or, $239.14 = \frac{\pi \times d^2}{4}$

$\therefore d = 17.44 m.$

Provide diagmeter of 18M.

Provide overall depth (d) = 6M + 1.5 (FB)

$= 6.5m$

Bottom slope = 1:12.

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(58) solution;

Given; $Q_{sewage} = 6.5 \times 10^6$ l/day.

SS = 250mg/lit

Water content in fresh sludge $(m_1) = 95\%$.

" " " digested " $(m_2) = 80\%$.

Sp. gravity of sludge (s) = 1.02.

Digestion time = 2 months = 60 days.

Then;

Wt of solid removed (Ws) = 55% of 250

= 137.5 mg/lit

$= 137.5 \times 10^{-6} \times 6.5 \times 10^6$ kg/day

= 893.75 kg/day.

(1) $m_1 = 95\%$

$\therefore P_{s_1} = 5\%$

$$W_{s_1} = \frac{W_s \times 100}{P_s} = \frac{893.75 \times 100}{5} = 17875 \text{ kg/day}.$$

$$V_{s_1} = \frac{W_{s_1}}{\gamma_w \times S_{s_1}} = \frac{17875}{1000 \times 1.02} = 17.524 m^3$$

$\therefore$ Volume of fresh sludge $(V_f) = 17.524 m^3$.

(2) $M_2 = 80\%$

$P_{s_2} = 20\%$.

$$W_{s_1} = \frac{893.75 \times 100}{20} = 4468.75 \text{ kg/day}.$$

$$V_{s_1} = \frac{W_{s_1}}{\gamma_w \times S_{s_1}} = 4.381 m^3$$

Volume of digested sludge $(V_d) = 4.381 m^3$

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Assume digestion progress is parabolic & no monsoon chang.

$$V = \left[V_f - \frac{2}{3}(V_f - V_d)\right] T_d$$

$$= \left[17.524 - \frac{2}{3}(17.524 - 4.881)\right] \times 60$$

$$= 525.72 m^3$$

Assume effective depth $(d) = 7m$.

$\therefore$ Surface area $(A) = \frac{V}{d} = \frac{525.72}{7} = 75.10 m^2$

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

$$\therefore \phi = \sqrt{\frac{4 \times 75.10}{\pi}} = 9.77 m$$

Provide $\phi = 10m$

Overall depth $= 7 + 0.5 = 7.5$

Bottom slope $= 1:12$.

(59) solution.

Maximum flow of sewage $= 55 \times 10^6 l/day = 0.6365 m^3/s$

Sp. gravity of grit $= 2.7$.

Size of grit particle to be removed $= 0.21 mm$

Assume temp^r $(T) = 20°C$.

$$\text{Settling velocity} (V_s) = 60.6 (S_g - 1) d_g \frac{3T + 70}{100}$$

$$= 60.6 (2.7 - 1) \times 0.21 \times \frac{3 \times 20 + 70}{100}$$

$$= 28.124 mm/sec.$$

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Assume detention time (T) = 60sec.

Capacity of tank (V) = $Q \times t$

$= 0.6365 \times 60$

$= 38.19 m^3$.

Effective depth (d) = $V_s \times T$

$= .28124 \times 10^{-3} \times 60$

$= 1.687m$.

Area of grit chamber = $\frac{V}{d} = 22.637 m^2$

Provide 2 parallel units

$A = \frac{22.637}{2} = 11.31 m^2 \cong 11.5 m^2$

Adopt width (B) = 1m

Length = 11.5m

free board = 0.3m

Overall depth = 1.687 + 0.3 = 2.0m

Horizontal velocity $(V_a) = \frac{Q}{Bd} = \frac{\frac{0.6365}{2}}{1 \times 1.687} = 0.188 m/sec$.

∴ Critical velocity $(V_c) = \sqrt{\frac{8k}{f}(S_g - 1) g d_s}$

$= \sqrt{\frac{8 \times 0.06}{0.05}(2.6 - 1) \times 9.81 \times 0.2 \times 10^{-3}}$

$= 0.22 m/s > 0.188 m/s$ ok

Hence provide 3 parallel units of grit chamber of $11.5 \times 1 \times 2$ with one extra unit.

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Tutorial 7.

Q1) Solution;

Given; Number of user = 10.

Assume $R = 0.05 m^3/person/year$.

$N = \cancel{10yr.}\ 3yr$

Volume (V) = $NRT = 10 \times 0.05 \times 3 = 1.5 m^3$.

Assume effective depth (d) = 1m.

Plan area (A) = $\frac{V}{d} = \frac{1.5}{1} = 1.5 M^2$

If ϕ be the diameter.

$$\phi = \sqrt{\frac{4 \times 1.5}{\pi}} = 1.381 m \simeq 1.5 m$$

Free board = 0.5

Total depth = 1 + 0.5 = 1.5 m

∴ Provide a pit of diameter 1.5m & depth = 1.5.

Q2) Solution;

Given; Number of user (N) = 100.

Sewage flow (Q) = 135 l/head/day.

Infiltration rate of soil = 20 min/cm.

Then; Assume detention time (t) = 1 day

i) Volume of sewage (V_1) = $Q \times t = 135 \times 100 \times 1 = 13500 l = 13.5$

ii) Volume for sludge digestion (V_2) = $0.0425 m^3/head$

$= 4.25 m^3$

iii) Volume for storage of digested sludge (V_3) = $C_{ds}\ m^3/head$

Assume desludging period = 3yr.

$= 0.0850 m^3$

$= 8.50 m$

∴ Volume (V) = $V_1 + V_2 + V_3 = 26.25 m^3$

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Assume effective depth = 1m.

$$\text{Area} = V/d = \frac{26.25}{1} = 2625 m^2$$

Assume $L/B = 3$

$\therefore L = 3B$

Area = L × B

or, $26.25 = 3B^2$

$\therefore B = 2.958 m \simeq 3m.$

$L = 3B = 3 \times 3 = 9m.$

free board = 0.4

$\therefore$ Overall depth = 1 + 0.4 = 1.4m.

So provide a septic tank with dimension 9m × 3m × 1.4m.

Dispersion trench.

Infiltration rate (t_r) = 20 min/cm.

$$I = \frac{130}{\sqrt{t_r}} = \frac{130}{\sqrt{20}} = 29.06 l/m^2/day$$

$$A = \frac{Q}{I} = \frac{13500 l/day}{29.06} = 464.41 m^2$$

Assume width = 1m

$L = 464.41m$

Maxm ~~depth~~ length ≯ 30m

$$\therefore \text{No. of trench} = \frac{464.41}{30} = 15.48 \simeq 16 \text{ number.}$$

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63) Solution;

Given; No. of user = 20.

Rate of sewage (q) = 80 lpcd.

Dentention time (t) = 24 hrs = 1 day.

Desludging time (T) = 3 yrs.

Absorption value of soil (I) = 100 l/m²/day.

Then;

Volume of settling of sewage $(V_1) = 80 \times 20 = 1600\, l/day$

$= 1.6 m^3$.

Volume for sludge digestion$(V_2) = 0.0425 m^3$/person

$= 0.0425 \times 20$

$= 0.85 m^3$

Volume for storage of digested sludge $(V_3) = 0.0850 m^3$/pe

$= 1.7 m^3$

$\therefore$ Volume $(V) = V_1 + V_2 + V_3$

$= 4.15 m^3$

Assume effective depth = 1m.

$\text{Area} = \frac{V}{d} = 4.15 m^2$

$\therefore$ Assume $L/B = 3$ $\therefore L = 3B$

$\therefore 4 = 3B^2$

or $\sqrt{\frac{4.15}{3}} = B$

$\therefore B = 1.17m$ or $1.2m$

$L = 3B = 3.6m$

Provide FB = 0.4m $\therefore$ overall depth = 1.4

$\therefore$ Dimension = 3.6m × 1.2m × 1.4m.

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For the design of soak pit.

Given $I = 1000\ l/m^2/day$.

$$Area = \frac{Q}{I}$$

or, $\pi D \cdot d = \dfrac{1600\ l/day}{1000\ l/m^2/day}$

or, $\pi \times \cancel{d} \times 1.5 = 1.6$

$\therefore \cancel{d} = 3.39m$

Provide depth $\simeq 3.4m$.

Spacing between consecutive pit $= 3 \times 1.5$
$= 4.5m$.

Assume GWT depth $> 3.5 + 2$
$> 5.5\ m$.

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(32) Solution;

Given $Q_r = 1 m^3/sec$.
$BOD_r = 4 mg/lit$
$Q_{se} = 0.25 m^3/sec$.
$BOD_{se} = 20 mg/l$.
$DO_s = 4 mg/l$.
Average velocity $(V) = 0.15 m/s$

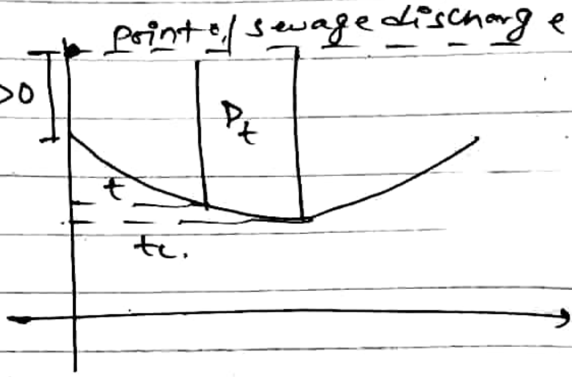
Also; $k = 0.12/day$
$R = 0.30/day$.
Saturation DO $= 9.17 mg/l$

To find;

DO deficit at 20 km & 40 km downstream = ?

We have

$$D_t = \frac{kL_0}{R-k}\left[10^{-kt} - 10^{-Rt}\right] + D_0 10^{-Rt}$$



$$BOD_{mix} = \frac{BOD_r \times Q_r + BOD_s \times Q_s}{Q_r + Q_s}$$

$$= \frac{4 \times 1 + 20 \times 0.25}{1 + 0.25}$$

$$= 7.2 mg/lit.$$

$BOD_5 = Y_5 = L_0(1 - 10^{-kt})$

or, $7.2 = L_0(1 - 10^{-0.12 \times 5})$

$\therefore L_0 = 9.615 mg/lit$.

$$DO_{mix} = \frac{9.17 \times 1 + 4 \times 0.25}{1 + 0.25}$$

$$= 8.136 mg/lit.$$

$\therefore DO = 9.17 - 8.136$
$= 1.034 mg/lit$

$\therefore$ (a) At 20 km; $t = \frac{d}{V} = \frac{20 \times 10^3}{0.15} = 1.54 day$.

$$D_t = \frac{0.12 \times 9.615}{0.3 - 0.12}\left[10^{-0.12 \times 1.54} - 10^{-0.3 \times 1.54}\right] + 1.034 \times 10^{-0.3 \times 1.54}$$

$= 2.33 mg/lit$.

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At 40km downstream

$$t = \frac{d}{V} = \frac{40\times10^3}{0.15} = 3.086 \text{days}.$$

$$D_t = \frac{0.12\times9.615}{0.3-0.12}\left[10^{-0.12\times3.086} - 10^{-0.3\times3.086}\right] + 1.034\times10^{-0.3\times3.086}$$

$= 2.09 \text{mg/lit}.$

(33) solution;

Given; $Q_{sewage} = 120 m^3/sec.$

$Q_{river} = 1600 m^3/sec.$

Velocity $(V) = 0.1 m/s.$

BOD_5 of sewage $= 250$ mg/lit.

$K = 0.1$/day

$f_s = 3.5 = R/K$ i.e $R = 0.35$/day

Saturation DO $= 9.2$ mg/lit

To find; Amount of critical DO deficit = ?

Time & distance it will occur = ?

Then;

Assume; $DO_{sewage} = 0$ mg/lit

$BOD_{river} =$ ~~9.2mg/lit~~ 0 mg/lit.

~~$BOD_{min} = \frac{1600\times9.2+120\times0}{1600+120} = 8.55 m^3/sec.$~~

~~DO_{min}~~ =

$$BOD_{min} = \frac{250\times120+1600\times0}{120+1600} = 17.44 \text{mg/lit}$$

$$DO_{min} = \frac{9.2\times1600}{120+1600} = 8.55 \text{mg/lit}.$$

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