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CIVIL ENGINEERING

ENVIRONMENTAL ENGINEERING

Volume - 1 : Study Material with Classroom Practice Questions



Environmental Engineering

Solutions for Volume : I Classroom Practice Questions

Water Supply Engineering

Chapter- 1 Population Forecasting & Water Demands

01. Ans: (c)

Sol:

1970	1980	1990	2000
40000	47000	53000	58000

$$\underbrace{\quad\quad\quad}_{7000} \quad \underbrace{\quad\quad\quad}_{6000} \quad \underbrace{\quad\quad\quad}_{5000}$$

$$\bar{x} = \frac{7000 + 6000 + 5000}{3} = 6000$$

$$P_n = P_o + n\bar{x}$$

$$n = \frac{2010 - 2000}{10}$$

$$n = 1$$

$$P_{2010} = P_1 = P_o + 1\bar{x}$$

$$P_1 = 58000 + 1(6000) = 64000$$

02. Ans: (c)

Sol:

Time	Population	Per decade % age increased in Population
1	1	
2	1.4	$\frac{1.4-1}{1} \times 100 = 40$
3	1.68	$\frac{1.68-1.4}{1.4} \times 100 = 20$

$$\bar{r} = (r_1 \times r_2)^{1/2}$$

$$\bar{r} = (40 \times 20)^{1/2}$$

$$\bar{r} = 28.28\%$$

$$P_o = 1.68 \text{ lakh}$$

$$P_1 = P_o \left(1 + \frac{\bar{r}}{100}\right)^1$$

$$P_1 = 1.68 \left(1 + \frac{28.28}{100}\right)^1$$

$$P_1 = 2.15 \text{ lakh} = 2.20 \text{ lakh}$$

03. Ans: 1.37, 1.97 billion

Sol: K = 1.6% per year

$$P_{2000} = 1 \text{ billion}$$

$$P_{2020} = ?$$

$$P_{2020} = P_{2000} \cdot e^{k(2020-2000)}$$

$$P_{2020} = 1 \times e^{\frac{1.6}{100}(20)}$$

$$P_{2020} = 1.37 \text{ billion}$$

04. Ans: 68000

Sol: $\bar{x} = 5000$ per decade

$$\bar{y} = 500 \text{ per decade}$$

$$P_{2020} = ?$$

$$P_{1990} = 50000 \text{ (given)}$$

$$n = \frac{2020 - 1990}{10} = 3$$

$$P_{2020} = P_{1990} + 3\bar{x} + \frac{3(3+1)}{2} \cdot \bar{y}$$



$$P_{2020} = 50000 + 3 \times 5000 + \frac{3 \times 4}{2} \times 500$$

$$P_{2020} = 68000$$

05. Ans: 743900

Sol:

Year	Population	Per decade increased in Population	Incremental over increase in population
1960	250000		
1970	480500	230500	-160700
1980	550300	69800	+18500
1990	638600	88300	-31700
2000	695200	56600	

$$\bar{x} = \frac{230500 + 69800 + 88300 + 56600}{4}$$

$$\bar{x} = 111300$$

$$\bar{y} = \frac{-160700 + 18500 - 31700}{3}$$

$$\bar{y} = -57966.67$$

$$P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2} \cdot \bar{y}$$

$$P_{2000} = ?$$

$$P_0 = 695200, \quad n = \frac{2000 - 1980}{10} = 2$$

$$P_{2000} = 695200 + 2 \times 111300 + \frac{2(2+1)}{2} (-57966.67)$$

$$P_{2000} = 743900$$

Per capita water supply = 200 lpcd

$$Q_{2020} = P_{2020} \times \text{per capita water supply}$$

$$= 743900 \times 200 \times 10^{-6} \text{ MLD}$$

$$= 148.7 \text{ MLD} = 149 \text{ MLD}$$

06. Ans: 1540000

Sol:

Time	Population	Per decade increased in Population	Per decade % age increased in population
1	400000	158500 (dP ₁)	
2	558500	217500 (dP ₂)	$\frac{158500}{400000} \times 100 = 39.6\%$
3	776000	322500 (dP ₃)	$\frac{217500}{558500} \times 100 = 38.94\%$
4	1098500		$\frac{322500}{776000} \times 100 = 41.5\%$
5	?		

If $dP_1 < dP_2 < dP_3 \rightarrow$ Geometric increase used

$$\bar{r} = (39.6 \times 38.94 \times 41.5)^{1/3} = 39.99\% = 40\%$$

$$P_n = P_0 \left(1 + \frac{\bar{r}}{100} \right)^n$$

$$P_5 = 1098500 \left(1 + \frac{40}{100} \right)^1 \approx 1540000$$

07. Ans: (c)

Sol: $P_0 = 28,000$

Average increase per decade,

$$\bar{x} = \frac{44,000 - 28,000}{2} = 8,000$$

4200m³/d required for 28,000 persons

6000m³/d sufficient for ----- persons

$$= \frac{28000 \times 6000}{4200} = 40,000$$

$$P_n = P_0 + n\bar{x}$$

$$40,000 = 28,000 + n(8,000)$$

$$n = 1.5 \text{ decades} = 15 \text{ years}$$



08. Ans: 100765

Sol:

Year	Population	Per decade Percentage Increase in Population	Decrease in Percentage Increase
1960	55,500	14.77	2.84
1970	63,700	11.93	0.43
1980	71,300	11.5	–
1990	79,500	–	–

Per decade percentage increase in population

$$= \frac{63700 - 55500}{55500} \times 100 = 14.77\%$$

$$r_0 = 11.5$$

$$P_n = P_o \left[1 + \frac{r_0 - \bar{D}}{100} \right] \left[1 + \frac{r_0 - 2\bar{D}}{100} \right] \dots \left[1 + \frac{r_0 - n\bar{D}}{100} \right]$$

P_o = latest known population

P_n = prospective population after n year

r_0 = latest per decade percentage increase in population

\bar{D} = average decrease in percentage increase

$$\bar{D} = \frac{2.84 + 0.43}{2}$$

$$\bar{D} = 1.635$$

$$n = \frac{2020 - 1990}{10} = 3$$

$$P_n = P_o \left[1 + \frac{r_0 - \bar{D}}{100} \right] \left[1 + \frac{r_0 - 2\bar{D}}{100} \right] \left[1 + \frac{r_0 - 3\bar{D}}{100} \right]$$

$$P_n = 79500 \left[1 + \frac{11.5 - 1.635}{100} \right] \left[1 + \frac{11.5 - 2(1.635)}{100} \right] \left[1 + \frac{11.5 - 3(1.635)}{100} \right]$$

$$= 79500 (1.09865) (1.0823) (1.06595)$$

$$= 100765.29$$

$$\approx 100765$$

∴ Population for the year 2020 by decreasing rate of growth = 100765

Chapter- 2 Sources and Conveyance of Water

01. Ans: (a)

Sol: Wire mesh is wounded around a strainer pipe tube well to prevent entry of sand along with water.

∴ [Both statements are correct R is the correct reason for “A”].

02. Ans: (b)

Sol: Total area of slots required =

$$\frac{Q}{V} = \frac{8 \times 10^{-3}}{2 \times 10^{-2}} = \frac{m^3/s}{m^2/s} = 0.4 m^2$$

$$\text{Area of each slot} = (2 \times 10^{-3}) \times (0.2 \times 10^{-3}) = 4 \times 10^{-6} m^2$$

Number of slots required =

Total area of slots required

Area of each slot



$$= \frac{0.4}{4 \times 10^{-6}} = 1,00,000$$

$$\text{Length of pipe required} = \frac{\text{Total number of slots}}{\text{Slots/cm/Length}}$$

$$= \frac{100000}{100} \times \text{cm}$$

$$= 1000 \text{ cm} = 1 \text{ m}$$

03. Ans: (b)

Chapter- 3 Quality of Water

01. Ans: (d)

Sol: $\text{Ca}^{2+} = 160 \text{ mg}/\ell$

$$\text{Mg}^{2+} = 40 \text{ mg}/\ell$$

$$\text{TH} = \text{Ca}^{2+} \times \frac{50}{20} + \text{Mg}^{2+} \times \frac{50}{12}$$

$$\text{TH} = 160 \times \frac{50}{20} + 40 \times \frac{50}{12}$$

$$\text{TH} = 567 \text{ mg}/\ell \text{ as } \text{CaCO}_3$$

04. Ans: (c)

Sol: $\text{FTN} = \frac{A+B}{A} = \frac{25+175}{25}$

$$\text{FTN} = 8$$

05. Ans: (d)

Sol: The product of H^+ ions and OH^- ions in a stronger acids = 10^{-14}

11. Ans: (a)

Sol: $\text{TH} = 200 \text{ mg}/\ell \text{ as } \text{CaCO}_3$

$$\text{TA} = 250 \text{ mg}/\ell \text{ as } \text{CaCO}_3$$

$$\text{TH} < \text{TA}$$

$$\text{CH} = \text{TH} = 200 \text{ mg}/\ell$$

12. Ans: (d)

Sol: $\text{NCH} = \text{TH} - \text{CH}$

$$= 200 - 200 = 0$$

14. Ans: (d)

Sol: $(\text{pH})_1 = 7.2, (\text{H}^+)_1 = 10^{-7.2} \text{ mol}/\ell$

$$(\text{pH})_0 = 8.4, (\text{H}^+)_0 = 10^{-8.4} \text{ mol}/\ell$$

$$\text{H}^+ = \frac{(\text{H}^+)_1 + (\text{H}^+)_0}{2}$$

$$\text{H}^+ = \frac{10^{-7.2} + 10^{-8.4}}{2} = 3.3 \times 10^{-8} \text{ mol}/\ell$$

$$\text{pH} = \log_{10} \frac{1}{\text{H}^+} = \log_{10} \frac{1}{3.3 \times 10^{-8}}$$

$$\text{pH} = 7.47$$

15. Ans: (c)

Sol: $(\text{pH})_A = 4.4, (\text{H}^+)_A = 10^{-4.4} \text{ mol}/\ell$

$$(\text{pH})_B = 6.4, (\text{H}^+)_B = 10^{-6.4} \text{ mol}/\ell$$

$$\frac{(\text{H}^+)_A}{(\text{H}^+)_B} = \frac{10^{-4.4}}{10^{-6.4}} = 100$$

16. Ans: (a)

Sol: Sample A, $V_A = 300 \text{ ml}$

$$(\text{pH})_A = 7$$

$$(\text{H}^+)_A = 10^{-7} \text{ mol}/\ell$$

Sample B, $V_B = 700 \text{ ml}$



$$(pH)_B = 5$$

$$(H^+)_B = 10^{-5} \text{ mol/lit}$$

$$C_{\text{mix}} = \frac{V_A C_A + V_B C_B + \dots}{V_A + V_B + \dots}$$

$$(H^+)_{\text{mix}} = \frac{300 \times 10^{-7} + 700 \times 10^{-5}}{300 + 700}$$

$$(H^+)_{\text{mix}} = 7.03 \times 10^{-6} \text{ mol/lit}$$

$$(pH)_{\text{mix}} = \log_{10} \frac{1}{(H^+)_{\text{mix}}} = \log_{10} \frac{1}{7.03 \times 10^{-6}}$$

$$(pH)_{\text{mix}} = 5.15$$

17. **Ans: (d)**

Sol: $CO_3^{--} = 90 \text{ mg/l}$

$$HCO_3^- = 61 \text{ mg/l}$$

$$TA = CO_3^{--} \times \frac{50}{30} + HCO_3^- \times \frac{50}{61}$$

$$TA = 90 \times \frac{50}{30} + 61 \times \frac{50}{61}$$

$$TA = 200 \text{ mg/l as } CaCO_3$$

18. **Ans: (d)**

Sol: From 10 – 1 – 0.10 (MPN) against 4 – 3 – 1,

+Ve grouping

$$MPN = 33$$

For 1 – 0.1 – 0.01 dilution against 4 – 3 – 1

+ve group

$$MPN = 33 \times \frac{\text{Table dilution}}{\text{Test dilution}}$$

$$MPN = 33 \times 10 = 330 \text{ no/100 ml}$$

19. **Ans: (a)**

Sol: $pH = 9$

$$H^+ = 10^{-9} \text{ mol/lit}$$

$$OH^- = 10^{-5} \text{ mol/lit}$$

$$OH^- \text{ mol/lit} = OH^- \times \text{Mol. wt. of } OH^- \times 1000$$

$$OH^- = 10^{-5} \times 17 \times 1000 = 0.17 \text{ mg/lit}$$

$$OH^- = 0.17 \times \frac{50}{17} = 0.50 \text{ mg/lit as } CaCO_3$$

27. **Ans: (d)**

Sol: $TA = 250 \text{ mg/l as } CaCO_3$

$$TH = 350 \text{ mg/l as } CaCO_3$$

$$TH > TA$$

$$CH = TA = 250 \text{ mg/l}$$

$$NCH = TH - CH = 350 - 250$$

$$NCH = 100 \text{ mg/l as } CaCO_3$$

28. **Ans: (c)**

Sol: $TH = Ca \times \frac{50}{20} + Mg \times \frac{50}{12.2}$

$$TH = 55 \times \frac{50}{20} + 10 \times \frac{50}{12.2} = 178.48$$

$$TH \approx 179 \text{ mg/l as } CaCO_3$$

Common data for Q 29 & 30

29. **Ans: (a)**

Sol: TH in mg/lit as $CaCO_3$

$$= Ca^{++} \text{ in mg/lit} \times \frac{50}{20} + Mg^{++} \text{ in mg/lit} \times \frac{50}{12}$$

$$= (12 \times 20) \times \frac{50}{20} + (18 \times 12) \times \frac{50}{12}$$

$$= 1500 \text{ mg/lit as } CaCO_3$$



30. Ans: (c)

Sol: Alkalinity in mg/lit CaCO_3

$$\begin{aligned} &= \text{HCO}_3^- \text{ in mg/lit} \times \frac{50}{61} + \text{CO}_3^{2-} \text{ in mg/lit} \times \frac{50}{30} \\ &= (30 \times 61) \times \frac{50}{61} + (5 \times 30) \times \frac{50}{30} \\ &= 1750 \text{ mg/lit as } \text{CaCO}_3 \end{aligned}$$

Common data for Question Nos. 31. & 32

31. Ans: (c)

Sol: $\text{TH} = 100 \times \frac{50}{20} + 6 \times \frac{50}{12}$
 $= 275 \text{ mg/lit as } \text{CaCO}_3$

32. Ans: (a)

Sol: Alkalinity $= 250 \times \frac{50}{61}$
 $= 204.9 \approx 205 \text{ mg/lit as } \text{CaCO}_3$

33. Ans: (d)

Sol: Tomoto juice $\text{pH} = 4.1$

$$\text{pH} = \log_{10} \frac{1}{\text{H}^+}$$

$$4.1 = \log_{10} \frac{1}{\text{H}^+}$$

$$\text{H}^+ = 10^{-4.1} \text{ mol/lit}$$

$$\text{H}^+ = 7.94 \times 10^{-5} \text{ mol/lit}$$

34. Ans: (d)

Sol: $\text{OH}^- = 10^{-5.6} \text{ m.mol/lit}$

$$\text{OH}^- = 10^{-5.6} \times 10^{-3} \text{ mol/lit}$$

$$\text{OH}^- = 10^{-8.6} \text{ mol/lit}$$

$$\text{H}^+ = \frac{10^{-14}}{10^{-8.6}} = 10^{-5.4} \text{ mol/lit}$$

$$\text{pH} = \log_{10} \frac{1}{\text{H}^+} = \log_{10} \frac{1}{10^{-5.4}}$$

$$\text{pH} = 5.4$$

36. Ans: (d)

Sol:

From table 10-1-0.10 (MPN) against

2-1-0 +ve group

$$\text{MPN} = 7$$

For 1-0.1 -0.01 dilution against

2-1-0, +ve group

$$\text{MPN} = 7 \times \frac{\text{table dilution}}{\text{test dilution}}$$

$$\text{MPN} = 7 \times 10 = 70$$

37. Ans: (b)

Sol: Mol. Wt of $\text{CO}_3 = 12 + 3 \times 16 = 60$

Mol. Wt. of Ca = 40

60 parts of CO_3 required = 40 parts of Ca

$$1 \text{ part of } \text{CO}_3 \text{ require} = \frac{40}{60} \text{ part of Ca}$$

$$\begin{aligned} 90 \text{ mg/l part of } \text{CO}_3 \text{ require} &= \frac{40}{60} \times 90 \text{ mg/l of Ca} \\ &= 60 \text{ mg/l of Ca} \end{aligned}$$

38. Ans: (c)

Sol: $\text{pH} = 9.25$

$$\text{pH} = \log_{10} \frac{1}{\text{H}^+}$$



$$9.25 = \log_{10} \frac{1}{H^+}$$

$$H^+ = 10^{-9.25} \text{ mol/lit}$$

$$[H^+][OH^-] = 10^{-14}$$

$$[OH^-] = \frac{10^{-14}}{10^{-9.25}} = 10^{-4.75} \text{ mol/lit}$$

$$OH^-(\text{mg}/\ell) = OH^-(\text{mg}/\text{l}) \times \text{Mol. Wt. of } OH^- \times 1000$$

$$OH^-(\text{mg}/\ell) = 10^{-4.75} \times 17 \times 1000$$

$$OH^- = 0.302 \text{ mg/l as CaCO}_3$$

39. Ans: (d)

$$\text{Sol: } \text{TON} = \frac{A+B}{A}$$

$$\text{TON} = \frac{187.5 + 12.5}{12.5}$$

$$\text{TON} = 16$$

40. Ans: (b)

$$\text{Sol: } OH^- = 17 \text{ mg/l}$$

$$OH^-(\text{mol/l}) = \frac{(OH^-)\text{mg/l}}{\text{Mol. wt. of } OH^- \times 1000}$$

$$OH^- = \frac{17}{17 \times 1000} = 10^{-3} \text{ mol/lit}$$

$$[H^+][OH^-] = 10^{-14} \text{ mol/lit}$$

$$H^+ = \frac{10^{-14}}{10^{-3}} = 10^{-11} \text{ mol/lit}$$

$$\text{pH} = \log_{10} \frac{1}{H^+} = \log_{10} \frac{1}{10^{-11}}$$

$$\text{pH} = 11$$

41. Ans: (b)

$$\text{Sol: } Ca^{2+} = 4 \text{ m.eq/lit}$$

$$Mg^{2+} = 1 \text{ m eq/lit}$$

$$HCO_3^- = 3.5 \text{ m. eq/lit}$$

$$\text{TH} = Ca^{2+} \times 50 + Mg^{2+} \times 50$$

(where Ca & Mg are in m.eq/lit)

$$= 4 \times 50 + 1 \times 50 = 250 \text{ mg/l as CaCO}_3$$

$$\text{TA} = CO_3 \times 50 + HCO_3 \times 50$$

(where CO_3 & HCO_3 in m.eq/lit)

$$= 0 + 3.5 \times 50 = 175 \text{ mg/l as CaCO}_3$$

$$\text{TH} > \text{TA}$$

$$\therefore \text{CH} = \text{TA} = 175 \text{ mg/l as CaCO}_3$$

$$\text{NCH} = \text{TH} - \text{CH} = 250 - 175$$

$$= 75 \text{ mg/l as CaCO}_3$$

44. Ans: 640, 220 & 420 mg/lit

$$\text{Sol: } W_1 = 98.42 \text{ gm}$$

$$W_2 = 98.484 \text{ gm}$$

$$W_3 = 98.462 \text{ gm}$$

$$\text{Total solids (TS)} = \frac{W_2 - W_1}{V}$$

$$\text{TS} = \frac{98.484 - 98.42}{100}$$

$$\text{TS} = 6.4 \times 10^{-4} \times 10^6 = 640 \text{ mg/l}$$

$$\text{Volatile solids: } \frac{W_2 - W_3}{V}$$

Volatile solid

$$= \frac{98.484 - 98.462}{100} \times 10^6$$

$$= 220 \text{ mg/l}$$



$$\begin{aligned} \text{Fixed solids} &= \frac{W_3 - W_1}{V} \\ &= \frac{98.462 - 98.42}{100} \times 10^6 \\ &= 420 \text{ mg/l} \end{aligned}$$

Chapter- 4
Plain Sedimentation

Common data for Qs. 1, 2 & 3

01. Ans: (b)

Sol: B = 6 m, L = 15 m, H = 3 m
Q = 2 MLD

$$\begin{aligned} \text{Surface over flow rate } V_0 &= \frac{2 \times 10^6}{6 \times 15 \times 24} \\ &= 926 \text{ lit/hr/m}^2 \end{aligned}$$

02. Ans: (d)

Sol: Detention time is

$$\begin{aligned} \text{Volume of setting tank} &= Q \times \text{D.T} \\ \text{DT} &= \frac{6 \times 15 \times 3}{\frac{2 \times 10^6}{24 \times 10^3}} = \frac{270}{83.33} = 3.24 \text{ hrs} \end{aligned}$$

03. Ans: (a)

Sol: $\eta = 70\%$, $V_0 = 926 \text{ lit/hr/m}^2$

$$\eta = \frac{V_s}{V_0} \times 100$$

$$\begin{aligned} \text{Total solids removed} \\ &= Q \times \text{concentration of solids (MLD} \times \text{mg/lit)} \\ &= 2 \times 70 \\ &= 140 \text{ kg/day} \end{aligned}$$

$$\begin{aligned} \text{Total amount of dry solids removed} \\ &= \text{Total amount of solids in water} \times \eta \\ &= 140 \times \frac{70}{100} = 98 \text{ kg/day} \end{aligned}$$

Common data for Qs. 04 & 05

04. Ans: (c)

Sol: Q = 1.8 MLD

D.T = 4 hours

V = ?

$$= \frac{1.8 \times 10^6}{10^3 \times 24} = 75 \text{ m}^3/\text{hr}$$

$$\begin{aligned} \text{Volume of tank} &= Q \times \text{DT} \\ &= 75 \times 4 = 300 \text{ m}^3 \end{aligned}$$

05. Ans: (b)

Sol: SOR = 500 lit/hr/m², L:B = 4:1, L = ?

$$V_0 = \frac{Q}{A}$$

$$\text{Surface area} = \frac{Q}{\text{SOR}} = \frac{1.8 \times 10^6}{24 \times 500}$$

$$L \times B = 150 \text{ m}^2$$

$$L \times \frac{L}{4} = 150 \text{ m}^2$$

$$L^2 = 150 \times 4 \Rightarrow L = 24.49 \text{ m}$$

06. Ans: 0.0112 m/sec

Sol: $V_H = ?$ L = 60 m, H = 3 m

$$\frac{L}{V_H} = \frac{H}{V_s}$$

$$V_s = \frac{g(s-1)d^2}{18\nu}$$



$$= \frac{9.81(2.65-1) \times (0.025 \times 10^{-3})^2}{18 \times \frac{0.01}{(100)^2}}$$

$$= 5.62 \times 10^{-4} \text{ m/sec}$$

$$\frac{60}{V_H} = \frac{3}{5.62 \times 10^{-4}}$$

$$\Rightarrow V_H = 0.0112 \text{ m/sec}$$

07. Ans: (c)

Sol: $Q = 100000 \text{ m}^3/\text{day}$

Settling velocity = 20 m/day

$$\text{Area of tank} = \frac{Q}{\text{Settling velocity}}$$

$$\text{Area of tank} = \frac{100000}{20} = 5000 \text{ m}^2$$

08. Ans: (a)

Sol: $d = 0.025 \text{ mm}$, $s = 2.65$, $v = 0.01 \text{ cm}^2/\text{sec}$

$$v_s = \frac{g(s-1)d^2}{18 \times v}$$

$$= \frac{9.81(2.65-1) \times (0.025 \times 10^{-3})^2}{18 \times 0.01 \times 10^{-4}}$$

$$= 0.056 \text{ cm/sec}$$

09. Ans: 27.08, 100%

Sol: $V_0 = 12,000 \text{ lit/hr/m}^2$, $d = 0.03 \text{ mm}$

$$= 12 \text{ m}^3/\text{hr/m}^2$$

$$V_s = \frac{g(s-1)d^2}{18 \times v}$$

$$= \frac{9.81(2.65-1)(0.03 \times 10^{-3})^2}{18 \times \frac{0.897}{(1000)^2}}$$

$$= V_s = 0.922 \text{ mm/sec}$$

$$V_s = 9.02 \times 10^{-4} \text{ m/sec}$$

$$\eta = \frac{V_s}{V_0} \times 100$$

$$V_0 = 12 \text{ m}^3/\text{hr/m}^2 = 3.33 \times 10^{-3} \text{ m/sec}$$

$$= \frac{9.02 \times 10^{-4}}{3.33 \times 10^{-3}} \times 100$$

$$= 27.08\%$$

b) $d = 12 \text{ mm} > 1 \text{ mm}$

$$V_s = 18 \sqrt{g(G-1)d}$$

$$= 18 \sqrt{9.81(2.65-1) \times (12 \times 10^{-3})}$$

$$\eta = \frac{V_s}{V_0} \times 100 = \frac{0.79 \times 100}{3.33 \times 10^{-3}} \times 100 = 100\%$$

Common Data for Qs. 10 & 11

10. Ans: (a)

Sol: $d = 26 \text{ m}$ with $H = 2.10 \text{ m}$

$Q = 13000 \text{ m}^3/\text{day}$, $D.T = ?$

$$DT = \frac{2.10 \times \left(\frac{\pi}{4} \times 26^2\right)}{\frac{13000}{24}} = 2.05 \text{ hrs}$$

11. Ans: (d)

Sol: Weir loading = $\frac{Q}{\text{length of weir}}$

$$= \frac{13000}{\pi \times 26}$$

$$= 159 \text{ m}^3/\text{day/m}$$



12. Ans: 44.5, 14.83 & 0.47

Sol: $d = 50 \mu\text{m} = 50 \times 10^{-3} \text{ m} = 0.05 \text{ m}$,

$G = 2.3$, $Q = 100 \text{ MLD}$, $H = 3 \text{ m}$

$L:B = 3:1$, $v = 1.01 \times 10^{-6} \text{ m}^2/\text{s}$

$$V_s = \frac{g(G-1)d^2}{18 \times v}$$

$$= \frac{9.81(2.3-1) \times (0.05 \times 10^{-3})^2}{18 \times 1.01 \times 10^{-6}}$$

$$V_s = 1.753 \times 10^{-3} \text{ m/sec}$$

For 100% removal

$$V_s = V_0 = 1.753 \times 10^{-3} \text{ m/sec}$$

$$\text{Surface area} = \frac{Q}{V_0} = \frac{1.157}{1.753 \times 10^{-3}}$$

$$L : 3B = 660.011$$

$$L \times B$$

$$3B \times B = 660.011$$

$$3B^2 = 660.011$$

$$B = \sqrt{\frac{660.011}{3}} = 14.83 \text{ m}$$

$$L = 3 \times B = 3 \times 14.83 = 44.49 \text{ m}$$

$$D.T = \frac{\text{Volume of tank}}{Q} = \frac{L \times B \times H}{Q}$$

$$\frac{44.49 \times 14.83 \times 3}{100 \times 10^6} = 0.47 \text{ hr}$$

$$\frac{24 \times 10^3}{24 \times 10^3}$$

13. Ans: 20 m³/m²/day

Sol: $L \times B \times H = 100 \times 50 \times 3 \text{ m}$,

$Q = 1,00,000 \text{ m}^3/\text{day}$

Surface flow rate -- ?, $\rho = 2.65 \text{ g/cc}$,

$v = 1.02 \times 10^{-2} \text{ cm}^2/\text{sec}$

$$\text{Surface flow rate} = \frac{Q}{\text{surface flow area}}$$

$$= \frac{100000}{100 \times 50}$$

$$= 20 \text{ m}^3/\text{m}^2/\text{day}$$

$$\text{For 100\% removal } V_s = V_0$$

$$= 20 \text{ m}^3/\text{m}^2/\text{day}$$

14. Ans: (c)

Sol: $H = 3 \text{ m}$, surface area $A_s = 900 \text{ m}^2$,

$Q = 8000 \text{ m}^3/\text{day}$, $T = 20^\circ\text{C}$,

$\mu = 10^{-3} \text{ kg/m-s}$, $\rho = 1000 \text{ kg/m}^3$,

$d = 0.01 \text{ mm}$, $G = 2.65$, $\eta = ?$

$$V_0 = \frac{Q}{A_s} = \frac{8000}{900} = 8.889 \text{ m}^3/\text{day}/\text{m}^2$$

$$= \frac{8.8}{24 \times 60 \times 60} \text{ m/sec} = 1.0185 \times 10^{-4} \text{ m/s}$$

$$V_s = \frac{g[\rho_p - \rho_w]d^2}{18}$$

$$= \frac{9.81(2650 - 1000) \times (0.01 \times 10^{-3})^2}{18 \times 10^{-3}}$$

$$V_0 = 8.99 \times 10^{-5} \text{ m/sec}$$

Proportion of particle removed 'η'

$$= \frac{V_s}{V_0} \times 100$$

$$= \frac{8.99 \times 10^{-5}}{1.018 \times 10^{-4}} \times 100 = 88.31\%$$



Common data for Question Nos. 15 & 16

15. **Ans: (a)**

Sol: L = 20 m, B = 10 m, H = 3 m, Q = 4 MLD,

$$T = 20^{\circ}\text{C}, \mu = 1.002 \times 10^{-3} \frac{\text{N-s}}{\text{m}^2} \text{ at } 20^{\circ}\text{C},$$

$$\rho_w = 998.2 \text{ kg/m}^3, G = 2.65$$

$$\text{Surface overflow} = \frac{Q}{\text{Surface area}}$$

$$= \frac{4 \times 10^6 \times 10^{-3}}{20 \times 10}$$

$$= 20 \text{ m}^3/\text{m}^2/\text{day}$$

16. **Ans: (b)**

Sol: $\eta = 100\%$

$$V_s = \frac{g(\rho_p - \rho_w)d^2}{18\mu}$$

$$G = 2.65, \rho_p = 2.65 \times \rho_w = 2.65 \times 998.2$$

$$\rho_p = 2645.23 \text{ kg/m}^3$$

$$\frac{20}{24 \times 60 \times 60} = \frac{9.81(2645.23 - 998.2)d^2}{18 \times 1.002 \times 10^{-3}}$$

$$d = 0.016 \text{ mm}$$

17. **Ans: (b)**

Sol: $V_{S1} = 0.1 \text{ mm/s}, V_{S2} = 0.2 \text{ mm/s},$

$$V_{S3} = 1.0 \text{ mm/s}$$

$$\text{Surface over flow rate} = 43.2 \text{ m}^3/\text{m}^2/\text{d}$$

Particle	Percentage	V_s mm/sec	$\eta = \frac{V_s}{V_0} \times 100$
1	10	0.1	$\eta_1 = \frac{0.1}{0.5} \times 100 = 20$
2	60	0.2	$\eta_2 = \frac{0.2}{0.5} \times 100 = 40$
3	30	1.0	$\eta_3 = \frac{1}{0.5} \times 100 = 100$

$$V_0 = 43.2 \text{ m}^3/\text{m}^2/\text{day}$$

$$V_0 = \frac{43.2 \times 10^6}{10^3 \times 24 \times 60 \times 60} = 0.5 \text{ mm/sec}$$

$$\text{Overall removal} = \sum P_i \eta_i$$

$$= \frac{10}{100} \times 20 + \frac{60}{100} \times 40 + \frac{30}{100} \times 100$$

$$= 56\%$$

18. **Ans: (b)**

Sol: $V_0 = 30 \text{ m}^3/\text{m}^2/\text{day}, S = 2.65$

$$\rho = 1000 \text{ kg/m}^3$$

$$\mu = 0.001 \text{ N-s/m}^2, 1 \text{ stoke} = 10^{-4} \text{ m}^2/\text{sec}$$

$$\rho_p = s \times \rho_w = 2.65 \times 1000 = 2650$$

$$\rho_w = 1000 \text{ kg/m}^3$$

$$V_s = \frac{g(\rho_p - \rho_w)d^2}{18\mu}$$

$$= \frac{9.81(2650 - 1000)d^2}{18 \times 0.001}$$

$$= \frac{30 \times 10^3}{24 \times 60 \times 60} = \frac{16186.5d^2}{0.018}$$

$$0.540 = 1.39851 \times 10^9 d^2$$

$$d = 1.965 \times 10^{-5}$$

$$d = 0.02 \text{ mm}$$



19. Ans: 3.124

Sol: $d = 0.06 \text{ mm} = 0.06 \times 10^{-3} \text{ m}$

$$g = 9.8 \text{ m/sec}^2$$

$$G = 2.65$$

$$v = 1.0105 \times 10^{-2} \text{ cm}^2/\text{sec}$$

$$V_s = \frac{g(G-1)d^2}{18v}$$

$$V_s = \frac{9.81 \times (2.65-1) \times (0.06 \times 10^{-3})^2}{18 \times 1.0105 \times 10^{-6}}$$

$$V_s = 3.20 \times 10^{-3} \text{ m/sec}$$

$$\text{Surface area} = \frac{Q}{V_s}$$

$$A = \frac{0.01}{3.20 \times 10^{-3}} = 3.124 \text{ m}^2$$

20. Ans: 22.576

Sol: $\eta = \frac{V_s}{V_o} \times 100$

$$V_o = 40 \text{ m}^3/\text{m}^2/\text{day} = 40 \text{ m/day}$$

$$= 4.629 \times 10^{-4} \text{ m/sec}$$

$$\eta = \frac{V_s}{V_o} \times 100$$

$$\Rightarrow 90 = \frac{V_s}{4.629 \times 10^{-4}} \times 100$$

$$V_s = 4.166 \times 10^{-4} \text{ m/sec}$$

$$V_s = \frac{g[s-1]d^2}{18\gamma}$$

$$\Rightarrow 4.166 \times 10^{-4} = \frac{9.81[2.65-1]}{18 \times 1.1 \times 10^{-6}} d^2$$

$$d = 22.576 \times 10^{-6} \text{ m}$$

$$= 22.576 \text{ } \mu\text{m}$$

21. Ans: 112.66

Sol: Surface overflow rate

$$V_o = 32.5 \text{ m}^3/\text{day}/\text{m}^2$$

$$L = 32.5 \text{ m}, B = 8.0 \text{ m}, D = 2.25 \text{ m}$$

$$L \times B = \frac{Q}{V_o}$$

$$\Rightarrow 32.5 \times 8 = \frac{Q}{32.5}$$

$$Q = 32.5 \times 8 \times 32.5 \text{ m}^3/\text{day}$$

$$\text{Weir loading rate} = \frac{Q}{\text{Length of weir}}$$

$$= \frac{32.5 \times 8 \times 32.5}{75}$$

$$= 112.66 \text{ m}^3/\text{day}/\text{m}$$

22. Ans: (d)

Sol: $v_s \propto d^2$

If 'd' doubles it increase by 4 times.

\therefore Assertion A is incorrect & reason R is correct

23. Ans: (d)

Sol: The important design parameter in the design of settling tank is surface overflow rate which also influence particle removal.

24. Ans: (b)

Given:

$$V_s = 3 \text{ m}^3/\text{hour}/\text{m}^2$$



Particle type	Settling velocity	Concentration	$\eta = \frac{U_s}{V_o} \times 100$	Concentration particles removed	X
I	3	200	$\frac{3}{3} \times 100 = 100$	$200 \times \frac{100}{100} = 200$	0
II	1	300	$\frac{1}{3} \times 100 = 33.33$	$300 \times \frac{33.33}{100} = 100 \text{ mg/l}$	200 Mg/l

26. Ans: (b)

Sol: $V = 2500 \text{ m}^3$

$Q = 25 \times 10^6 \text{ lit/day}$

DT = ?

$$D.T = \frac{V}{Q} = \frac{2500}{\frac{25 \times 10^6}{10^3}} = \frac{2500 \times 10^3}{25 \times 10^3} = \frac{24}{10} \text{ hr}$$

27. Ans: (a)

Sol: Pan area = $A_s = 100 \text{ m}^2$

$Q = 2400 \text{ m}^3/\text{day}$

$V_s = ?$

$$V_o = \frac{Q}{A_s} = \frac{2400}{100} = 24 \text{ m/day}$$

For 100%

$V_s = V_o = 24 \text{ m/day}$

$$\Rightarrow \frac{24}{24} \text{ m/day} = 1 \text{ m/day}$$



28. Ans: (b)

Sol:

Particle	Settling velocity (m/hr)	Initial concentration (mg/l)	$n \times C_{in}$ mg/l
1	1	100	$n_1 = \frac{1}{1} \times 100 = 100$
2	0.5	100	$n_2 = \frac{0.5}{1} \times 100 = 50$
3	0.1	100	$n_3 = \frac{0.1}{1} \times 100 = 10$
4	0.05	100	$n_4 = \frac{0.05}{1} \times 100 = 5$
			Total = 165 mg/l

$$= V_o = 1 \text{ m}^3/\text{m}^2/\text{hour}$$

$$= V_o = 1 \text{ m/hour}$$

Concentration of particle removed = 165 mg/l

Chapter- 5 Coagulation

Common Data Question 01 & 02

01. Ans: (c)

Sol: $Q = 10\text{MLD} = 10 \times 10^6 \text{ lit/day}$

Alum = 20 mg/lit

1 mg of Alum requires 0.45 mg of Alkaline as CaCO_3

\therefore 20 mg/Lit of alum requires

$= 20 \times 0.45 = 9 \text{ mg of alkaline as } \text{CaCO}_3 \text{ per}$

Lt of water

\therefore Total alkalinity matching filter

Alum = 9 mg/Lit = $10 \times 10^6 \text{ Lit/day}$

$= 90 \times 10^6$

Total alkalinity requirement

$(10^6 \text{ mg per day}) = 90$

02. Ans: (d)

Sol: Natural available alkalinity = 6 mg/ Lit

\therefore Alkalinity to be added additionally

$= 9 - 6 = 3 \text{ mg/Lit}$

\therefore Alkaline to be added to the water

$= 3 \times 0.56 = 1.68 \text{ mg/Lt}$

Total quick lime required per year



$$= \frac{1.68 \times 10 \times 10^6 \times 365}{10^6}$$

Total quick lime required (10^6 mg per year)
= 6132

03. Ans: 168 kg/day, 5.55 mg/l

Sol: Alum required in order to total = 12 MLD

Alum dose requirement = 14 ppm

CO₂ gas = ?

Total alum requirement/day

$$= Q \times \text{alum dose}$$

$$= 12 \times 14 = 168 \text{ kg/day}$$



Molecular weight of alum = 666

Molecular weight of 6CO₂ = 6[C(O₂)]

$$= 6[12 + 2 \times 16]$$

$$= 264$$

666 parts alum release = 264 parts of CO₂

$$1 \text{ part alum release} = \frac{264}{666} \text{ parts of CO}_2$$

$$14 \text{ mg/l of alum release} = \frac{264}{666} \times 14 \text{ mg/l of CO}_2$$

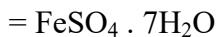
$$= 5.54 \text{ mg/l of CO}_2$$

04. Ans: 120 kg/day, 24.168 kg/day

Sol: Q = 12 MLD

Dosage of ferrous sulphate 10 mg/l

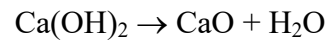
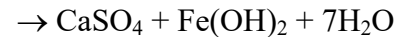
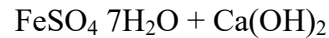
Total quantity of ferrous sulphate and lime-?



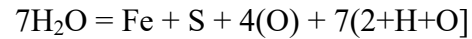
Total quantity of ferrous sulphate req/day

$$= Q \times \text{dosage of ferrous sulphate}$$

$$= 10 \times 12 = 120 \text{ kg/day}$$



Molecular weight of FeSO₄ .



Molecular weight of CaO = 56

278 parts of ferrous sulphate required

$$= 56 \text{ parts of CaO}$$

1 part of ferrous sulphate required

$$= \frac{56}{278} \text{ parts of CaO}$$

$$10 \text{ mg/l of ferrous} = \frac{56}{278} \times 10 \text{ mg/l as CaO}$$

$$= 2.014 \text{ mg/l}$$

Total lime as CaO required/day

$$= Q \times \text{dose of CaO}$$

$$= 12 \times 2.014$$

$$= 24.168 \text{ kg/day}$$

05. Ans: 37800 kg

Sol: Q = 35 m³/min = 50.4 MLD

Dose of alum = 25 mg/l

Total alum required in kg/day

$$= Q (\text{MLD}) \times \text{dose of alum (mg/l)}$$

$$= 50.4 \times 25 = 1260 \text{ kg/day}$$

Monthly alum requirement = 1260 × 30

$$= 37800 \text{ kg}$$



06. Ans: (b)

$$\text{Sol: } C_1 = \sqrt{\frac{P}{V\mu}}$$

$$600 = \sqrt{\frac{P}{2 \times 1 \times 10^{-3}}}$$

$$P = (600)^2 \times 2 \times 1 \times 10^{-3} = 720 \text{ Watts}$$

07. Ans: (d)

$$\text{Sol: } Q = 28800 \text{ m}^3/\text{d}$$

$$\rho_w = 1000 \text{ kg/m}^3$$

$$v = 10^{-6} \text{ m}^2/\text{sec}$$

$$G = 900 \text{ s}^{-1}$$

$$DT = 2 \text{ min}$$

$$\text{Volume of mixing basin} = Q \times DT$$

$$V = \frac{28800 \times 2}{24 \times 60} = 40 \text{ m}^3$$

$$G = \sqrt{\frac{P}{V\mu}}$$

$$900 = \sqrt{\frac{P}{40 \times 10^{-6} \times 1000}}$$

$$P = 32400 \text{ watts}$$

08. Ans: 1613.92 Watts

$$\text{Sol: } Q = 3000 \text{ m}^3/\text{hr}, \quad G = 40 \text{ sec}^{-1}$$

$$D.T = 20 \text{ min}, \quad \mu = 1.0087 \times 10^{-3} \text{ N-S/m}^2$$

$$\text{Volume} = Q \times DT = 3000 \times \frac{20}{60} = 1000 \text{ m}^3$$

$$\frac{L}{B} = 2, \quad D = 0.40B$$

$$L = 2B$$

$$\text{Surface area} = \frac{\text{Volume}}{\text{depth}} = \frac{1000}{0.40B}$$

$$L \times B = \frac{1000}{0.40B}$$

$$B \times 2B \times 0.40B = 1000$$

$$0.80B^3 = 1000$$

$$B = 10.77 \text{ m}, \quad L = 21.54 \text{ m}, \quad D = 4.3 \text{ m}$$

$$G = \sqrt{\frac{P}{v \cdot \mu}}$$

$$40 = \sqrt{\frac{P}{1000 \times 1.008 \times 10^3}}$$

$$P = 1613.92 \text{ Watts}$$

10. Ans: (b)

$$\text{Sol: } Q = 4.2 \text{ m}^3/\text{min}$$

$$V_0 = 0.2 \text{ mm/sec}; \quad d = 3.5 \text{ m}$$

$$V_0 = \frac{Q}{\text{surface area}}$$

$$0.2 \times 10^{-3} = \frac{4.2}{60 \times A}$$

$$A = 350 \text{ m}^2$$

11. Ans: (c)

Sol: High turbidity & high alkaline water predominant mechanism is sweep coagulation.

12. Ans: (b)

Sol: Sweep coagulation is dominant for high turbidity & high alkaline waters.



Chapter- 6
Filtration

01. Ans: 35.35 m, 17.67 m

Sol: P = 50,000 persons

$$\text{ROF} = 180 \text{ lit/hr/m}^2$$

$$Q = \text{Population} \times \text{per capita demand}$$

$$Q = 50,000 \times 150$$

$$= 7500000 \text{ lit/day}$$

$$\text{Design discharge } Q_{\text{density}} = 1.8 \times Q$$

$$= 1.8 \times 7500000$$

$$= 135 \times 10^5 \text{ lit/day}$$

$$\text{ROF} = 180 \text{ lit/hr/m}^2$$

$$\begin{aligned} \text{Total area of slow sand filter} &= \frac{Q_{\text{density}}}{\text{ROF}} \\ &= \frac{135 \times 10^5 \text{ lit/hr}}{180 \times 24 \text{ lit/hr/m}^2} = 3125 \text{ m}^2 \end{aligned}$$

$$\text{No. of filters in operations} = 5$$

(1 act as stand by)

$$\text{Area of each filter } L \times B$$

$$= \frac{\text{Total area}}{\text{no. of filters in operation}}$$

$$= \frac{3125}{5} = 625 \text{ m}^2$$

$$L : B = 2 : 1 \Rightarrow L = 2B$$

$$2B \times B = 625 \text{ m}^2$$

$$B^2 = 625/2$$

$$B = \sqrt{\frac{625}{2}} = 17.67 \text{ m}$$

$$L = 35.35 \text{ m}$$

02. Ans: 20 m, 10 m, 4.19%

Sol: Q = 24 MLD, ROF = 5 m³/hr/m²,

$$L:B = 2 : 1$$

$$Q = \frac{24 \times 10^6 \times 10^{-3}}{24} = 1000 \text{ m}^3/\text{hr}$$

$$\text{Total area of RSF req} = \frac{1000}{5} = 200 \text{ m}^2$$

$$\text{No. of filters} = 1$$

$$\text{Area of filter} = 200 \text{ m}^2$$

$$L : B = 200 \quad 2B \times B = 200$$

$$B^2 = \frac{200}{2}$$

$$B = 10 \text{ m}$$

$$L = 2 \times 10 = 20 \text{ m}$$

Volume of water filter b/w back wash

$$= \text{ROF} \times \text{duration of filtration} \times \text{area of each filter}$$

$$= 5 \times \left(24 - \frac{10}{60}\right) \times 200$$

$$= 23833.33 \text{ m}^3$$

Volume of water used in back wash ROF ×

DOB × area

$$= 6 \times 5 \times \frac{10}{60} \times 200 = 1000 \text{ m}^3$$

% of filter water used in back wash

$$= \frac{\text{volume of water filtered back wash}}{\text{volume of filtered b/w back}}$$

$$= \frac{1000}{23833.3} \times 100 = 4.19\%$$



03. Ans: 9.48 m, 4.74 m, 0.225 m³/sec

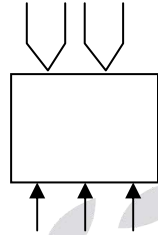
Sol: $Q = 0.25 \text{ m}^3/\text{sec}$, No. of filters = 4,

ROF = $5 \text{ m}^3/\text{m}^2/\text{hr}$

Back wash water, $10 \text{ l}/\text{m}^2/\text{sec}$,

$L : B = 2 : 1$

$L = ?, B = ?$



$$\begin{aligned} \text{Total area of RSF} &= \frac{Q}{\text{ROF}} = \frac{0.25}{5} \\ &= \frac{0.25 \times 60 \times 60}{6} \\ &= 180 \text{ m}^2 \end{aligned}$$

$$\text{Area of each filter} = \frac{180}{4} = 45 \text{ m}^2$$

$$L \times B = 45$$

$$2B \times B = 45$$

$$2B^2 = 45$$

$$B = \sqrt{\frac{45}{2}} = 4.74 \text{ m}$$

$$L = 2 \times 4.74 = 9.48 \text{ m}$$

Back wash water flow rate ROB

= velocity (V_B) \times Area of each filter

$$= 10 \times 45 = 450 \text{ lit}/\text{sec}$$

$$= 0.45 \text{ m}^3/\text{sec}$$

There are two troughs

$$\text{Flow through each wash water} = \frac{Q}{2}$$

$$= \frac{0.45}{2} = 0.225 \text{ m}^3/\text{sec}$$

04. Ans: 0.27 m

Sol: $V_s = 3 \text{ m}/\text{hr}$

$$L = 0.6 \text{ m}$$

$$\phi = 0.8$$

$$d = 0.5 \text{ mm}$$

$$e = 0.4$$

$$S = 2.65$$

$$v = 1 \times 10^{-6} \text{ m}^2/\text{sec}$$

$$\text{Re} = \frac{(V_s \cdot d)\phi}{v}$$

$$= \frac{3 \times (0.5 \times 10^{-3}) \times 0.8}{1 \times 10^{-6} \times 60 \times 60} = 0.33$$

$$f = \frac{150(1-n)}{\text{Re}} + 1.75$$

$$= \frac{150(1-0.4)}{0.33} + 1.75$$

$$= 271.75$$

$$h_f = \frac{f \cdot L \cdot V_s^2}{gd} \times \frac{(1-n)}{n^3 \times \phi}$$

$$= \frac{271.75 \times 0.6 \left(\frac{3}{60 \times 60} \right)^2}{9.81 \times 0.5 \times 10^{-3}} \times \frac{(1-0.4)}{0.4^3 \times 0.8}$$

$$= 0.27 \text{ m}$$

05. Ans: 0.032 m/sec, 0.6258 m

Sol: $d = 0.65 \text{ mm}$, $S = 2.66$, $n = 0.42$, $z = 65 \text{ cm}$

$$V_s = \frac{g(S-1)d^2}{18v}$$

$$= \frac{9.81(2.66-1) \times (0.65 \times 10^{-3})^2}{18 \times 1.3 \times 10^{-2} \times 10^{-4}}$$

$$= 0.29 \text{ mm}/\text{sec}$$

$$V_B = V_s(n_e)^{4.5}$$

$$\frac{z_e}{z} = \frac{1-n}{1-n_e}$$



$$\frac{1.5z}{z} = \frac{1-0.42}{1-n_e}$$

$$n_e = 0.613$$

$$V_B = 0.29(0.613)^{4.5} = 0.032 \text{ m/sec}$$

Head loss during back wash h_b

$$= z(1-n)(s-1)$$

$$= 0.65 (1-0.42) (2.66 - 1)$$

$$= 0.6258 \text{ m}$$

06. Ans: (a)

$$\text{Sol: } \frac{1}{Z_1} \ln \frac{100}{100-\eta_1} = \frac{1}{Z_2} \ln \frac{100}{100-\eta_2}$$

$$Z_1 = 0.05 \text{ m, } \eta_1 = 90\%, \eta_2 = 99\%$$

$$Z_2 = ?$$

$$\frac{1}{0.05} \ln \frac{100}{100-90} = \frac{1}{Z_2} \ln \frac{100}{100-99}$$

$$46.06 = \frac{1}{Z_2} \times 4.606$$

$$Z_2 = \frac{4.606}{46.06}$$

$$Z_2 = 0.10 \text{ m}$$

Common data for Question Nos. 07 & 08

07. Ans: (c)

$$\text{Sol: ROF} = 200 \text{ m}^3/\text{m}^2/\text{d},$$

$$Q = 0.5 \text{ m}^3/\text{s}, A = 50 \text{ m}^2$$

$$\text{Total area} = \frac{Q}{\text{ROF}} = \frac{0.5}{\frac{200}{24 \times 60 \times 60}} = 216 \text{ m}^2$$

08. Ans: (c)

$$\text{Sol: No. of filters} = \frac{216}{50} = 4.32 \approx 5$$

$$\text{Total no. of filters} = 6$$

11. Ans: 144 m³/day/m²

$$\text{Sol: } Q = 1 \text{ m}^3/\text{sec} = 86400 \text{ m}^3/\text{day}$$

$$\text{no. of filters} = 14$$

$$\text{surface area of each filter} = 50 \text{ m}^2$$

$$\text{no. of filters in working condition}$$

$$= 14 - 2 = 12$$

$$\text{Loading rate} = \frac{Q}{\text{surface area}} = \frac{86400}{12 \times 50} = 144 \text{ m}^3/\text{day}/\text{m}^2$$

12. Refer to ESE – Volume II (Objective) Book

13. Refer to ESE – Volume II (Objective) Book

14. Refer to ESE – Volume II (Objective) Book

15. Refer to ESE – Volume II (Objective) Book

16. Ans: 7.53

$$\text{Sol: ROF} : 200 \text{ m}^3/\text{day}/\text{m}^2 = \frac{200}{24} \text{ m}^3/\text{hr}/\text{m}^2$$

$$\text{ROB} : 1000 \text{ m}^3/\text{day}/\text{m}^2 = \frac{1000}{24} \text{ m}^3/\text{hr}/\text{m}^2$$

$$\text{DOB} : 15 \text{ min}$$

$$\text{Filter water wasted for 30 min}$$

$$\text{DOF} : 24 - \frac{15}{60} - \frac{30}{60} = 23.25 \text{ hr}$$



Amount of water filtered/day = ROF × DOF × (L × B)

$$= \frac{200}{24} \times (23.25) \times (L \times B)$$

Amount of water recycled & reused

$$= \text{ROB} \times \text{DOB} \times (L \times B) + \text{ROF} \times$$

Duration of maturation × (L × B)

$$= \frac{1000}{24} \times \frac{15}{60} \times (L \times B) + \frac{200}{24} \times \frac{30}{60} \times (L \times B) \rightarrow (2)$$

Percentage increase in filtered water

$$= \frac{\frac{1000}{24} \times \frac{15}{60} \times (L \times B) + \frac{200}{24} \times \frac{30}{60} \times (L \times B)}{\frac{200}{24} \times 23.25 \times (L \times B)} \times 100$$

$$= \frac{250 + 100}{4650} \times 100 = 7.526\%$$

Chapter- 7 Disinfection

01. Ans: (c)

Sol: Population = 20,000

per capita demand = 150 lit/day

$$Q = 20,000 \times 150$$

$$= \frac{3000000}{10^6} \text{ lit/day} = 3 \text{ MLD}$$

Bleaching powder = 0.2 mg/l

Cl₂ = 0.2 ppm = 0.2 mg/l

Ca(OCl)₂ = 30% available Cl₂

Bleaching powder

$$= \frac{\text{Cl}_2 \text{ dose}}{\% \text{ of Cl}_2 \text{ bleaching powder}}$$

$$= \frac{0.2}{\frac{30}{100}} = 0.66 \text{ mg/l}$$

Total bleaching powder required/day

$$= 3 \times 0.66$$

$$= 2 \text{ kg/day}$$

02. Ans: (c)

Sol: Q = 20,000 m³/day

Total Cl₂ used = 8 kg/day

Residual Cl₂ = 0.15 mg/l

Dose of Cl₂ = ?

Demand = ?

Total Cl₂ = Q × design of Cl₂

8 = 20,000 × dose of Cl₂ MLD

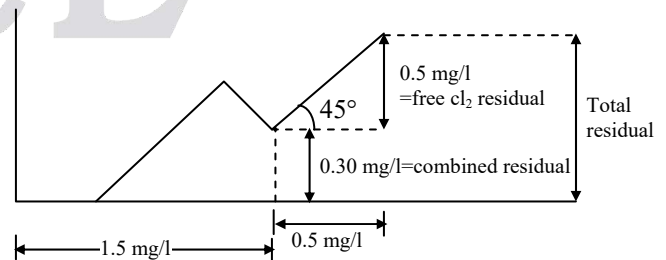
$$\text{Dose of Cl}_2 = \frac{8}{20} = 0.4 \text{ mg/l}$$

$$\text{Cl}_2 \text{ demand} = \text{Cl}_2 \text{ dose} - \text{Residual Cl}_2$$

$$= 0.4 - 0.15 = 0.25 \text{ mg/l}$$

03. Ans: (b)

Sol:



$$\text{Total residual} = 0.3 + 0.5 = 0.80 \text{ mg/l}$$



04. Ans: (b)

Sol:
$$\frac{\text{HOCL}}{(\text{HOCL} + \text{OCL})} = \frac{1}{1 + \frac{K_i}{H^+}}$$

$$0.9 = \frac{1}{1 + \frac{2.7 \times 10^{-8}}{H^+}}$$

$$H^+ = 2.7 \times 10^{-7} \text{ mol/lit}$$

$$\text{pH} = \log_{10} \left[\frac{1}{H^+} \right]$$

$$\text{pH} \approx 6.568$$

08. Ans: 3.2 min

Sol: Residual = 0.6 mg/l,

$$K = 3 \times 10^{-2} \text{ per sec}$$

t = ?

$$\% \text{ of kill} = \frac{N_o - N_t}{N_o} \times 100$$

$$99.7 = (1 - e^{-kt}) \times 100$$

$$99.7 = (1 - e^{-3 \times 10^{-2} t}) \times 100$$

$$99.7 = (0.029 \times t) \times 100$$

$$t = 193.63 \text{ sec} = \frac{193.63}{60} = 3.2 \text{ min}$$

09. Ans: 0.56 mg/lit

Sol: PH – 7 → Cl₂ required = 0.7 mg/l

PH – 8 → K = 2.7 × 10⁻⁸ what dosage of Cl₂?

$$H^+ = 10^{-7} \text{ mol/lit}; H^+ = 10^{-8} \text{ mol/lit}$$

% of HOCL at given pH,

$$\% \text{HOCL} = \frac{1}{1 + \frac{K}{H^+}} \times 100$$

$$\frac{1}{1 + \frac{2.7 \times 10^{-8}}{1 \times 10^{-7}}} \times 100 = 78.74\%$$

$$H^+ = 10^{-8} \text{ mol/lit}$$

$$\% \text{HOCL} = \frac{1}{1 + \frac{2.7 \times 10^{-8}}{10^{-8}}} \times 100 = 27.02\%$$

For a given degree of kill (% kill)

Cl₂ dose at any pH = Cl₂ dose at given pH ×

$$\frac{\% \text{HOCL at given pH}}{\% \text{HOCL at any pH}}$$

$$= 0.7 \times \frac{78.74}{27.02} = 2 \text{ mg/lit}$$

If pH is 6 then what amount of Cl₂

$$\% \text{HOCL} = \frac{1}{1 + \frac{K}{H^+}} \times 100$$

$$= \frac{1}{1 + \frac{2.7 \times 10^{-8}}{10^{-6}}} \times 100$$

$$= 97.37\%$$

$$\text{Cl}_2 \text{ dose} = 0.70 \times \frac{78.74}{97.37} = 0.56 \text{ mg / lit}$$

11. Ans: (c)

Sol: Percentage removal (%R)

$$= \left(\frac{10^6 - 10^2}{10^6} \right) \times 100 = 99.99\%$$

$$\log(R) = \log 10^6 - \log 10^2 = 6 - 2 = 4$$



12. Ans: (a)

Sol: Free residual

$$= \text{HOCL} + \text{OCL}^- = 2 \text{ mg / lit as } \text{Cl}_2$$

$$2(\text{mg / lit}) = \text{Cl}_2 \left(\frac{\text{moles}}{\text{lit}} \right) \times \text{Mol. wt} \times 1000$$

$$\frac{2}{2 \times 35.5 \times 1000} = \text{Cl}_2 \text{ (moles / lit)}$$

$$= 2.816 \times 10^{-5} \text{ (moles/lit)}$$

$$\text{pH} = 7.5 \quad \therefore \text{pH} = \log_{10} \left(\frac{1}{\text{H}^+} \right)$$

$$\text{H}^+ = 10^{-7.5} \text{ moles / lit}$$

$$\frac{\text{HOCL}}{\text{OCL}^-} = [\text{K}] [\text{H}^+] = 10^{7.5} \times 10^{-7.5}$$

$$\therefore \text{HOCL} = \text{OCL}^-$$

$$\text{HOCL} + \text{OCL}^- = 2 \text{ mg / lit}$$

$$= 2.816 \times 10^{-5} \text{ (moles / lit)}$$

$$\therefore 2 \text{ OCL}^- = 2.816 \times 10^{-5}$$

$$\therefore \text{OCL}^- = 1.408 \times 10^{-5} \text{ moles / lit}$$

13. Ans: (a)

Sol: Dose of bleaching powder = 2 mg/l

$$Q = \frac{10000 \times 50}{10^6} = 0.5 \text{ MLD}$$

$$\begin{aligned} \text{Total amount required} &= Q \times \text{Dose of} \\ &\quad \text{bleaching powder} \\ &= 0.5 \times 2 = 1 \text{ kg/day} \end{aligned}$$

14. Ans: (b)

Sol: Fraction of HOCL = $\frac{1}{1 + \frac{k}{\text{H}^+}}$

$$\text{pH} = 7 \Rightarrow \text{H}^+ = 10^{-7} \text{ mol/lit}$$

$$k = 2.5 \times 10^{-8} \text{ mol/lit}$$

$$= \frac{1}{1 + \frac{2.5 \times 10^{-8}}{10^{-7}}} = \frac{1}{1.25} = 0.8$$

15. Ans: (a)

Sol: $C^n t = \text{constant} \Rightarrow t \propto \frac{1}{C}$

C → Concentration of disinfectant

t → detention time (or) contact time

n → dilution factor.

$$\text{Contact time "t"} = \frac{\text{Volume of contact unit}}{\text{Flow rate}}$$

$$= \frac{V}{Q}$$

$$\therefore C^n t = \text{constant}$$

$$\therefore C_1^n t_1 = C_2^n t_2 = \text{constant}$$

$$C_1^n \frac{V}{Q_1} = C_2^n \frac{V}{Q_2}$$

$$\frac{C_1^n}{Q_1} = \frac{C_2^n}{Q_2}$$

$$C_1^n = \frac{\text{Total chlorine}}{Q}$$

$$C_1^n = \frac{32}{16} = 2 \text{ mg/l}$$

$$\frac{2}{16} = \frac{C_2^1}{22}$$

$$C_2 = 2 \times \frac{22}{16} = 2.75 \text{ mg/l}$$

∴ Total chlorine required for 22 MLD

$$= Q_2 \times C_2$$

$$= 22 \times 2.75 = 60.5 \text{ kg/day}$$



16. **Ans: 50.02 m³**

Sol: % sewage kill 'η' = $(1 - e^{-kt}) \times 100$

$$K = 0.145$$

$$98 = (1 - e^{-0.145 \times t}) \times 100$$

$$t = 26.979 \text{ min}$$

Volume of disinfection unit = $Q \times Dt$

$$= \frac{2670}{24 \times 60} \times 26.979 = 50.02 \text{ m}^3$$

17. **Ans: (c)**

Sol: Beyond break point any dose produces free chlorine residuals & they remain till water reaches to the consumer.

A is true but R is false.

18. **Ans: (a)**

Sol: Ammonia combines with chlorine and form chloramines. Chloramines produce long persistent residuals & protects water.

Both A & R true.

R is the correct explanation of A.

19. **Ans: (b)**

Sol. Any dose beyond break point is ensure free as well as combine residuals. Super high chlorine dose inactivates pathogens quickly.

Both A and R are true but R is not correct explanation of A.

20. Refer to ESE – Volume II(Objective) Book

21. Refer to ESE – Volume II(Objective) Book

22. **Ans: (d)**

Sol: Cl_2 available in Bleaching powder (B.P) =

$$0.3 \text{ mg/ml}$$

$$Cl_2 \text{ dose} = 0.1 \text{ mg/l}$$

Volume of water to be treated = 200 ml

Total amount of Bleaching powder required

= ?

$$\text{Bleaching powder required} = \frac{Cl_2 \text{ dose}}{Cl_2 \text{ in B.P}}$$

$$= \frac{0.1 \text{ mg/l}}{0.3 \text{ mg/ml}}$$

Total bleaching powder required = bleaching powder dose × Volume of water

$$= \frac{0.1}{0.3} \times \frac{200}{1000} \text{ ml}$$

23. **Ans: (d)**

Sol: Oxidising power of Cl_2 = 35.5

Oxidising power of $NHCl_2$ = 21.48

% of chlorine in $NHCl_2$

$$= \frac{\text{oxidising power of } NHCl_2}{\text{Oxidising power of } Cl_2} \times 100$$

$$= \frac{21.48}{35.5} \times 100$$

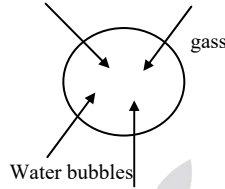
$$= 60\%$$



Chapter- 8
Miscellaneous Water Treatment

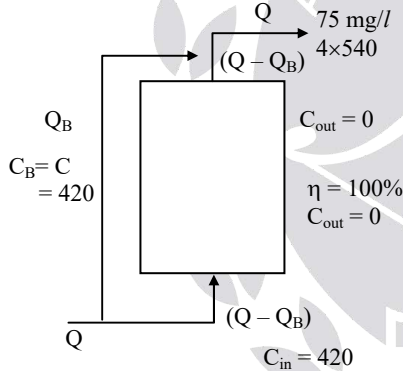
07. Ans: (b)

Sol: liquid-gas system absorption.



10. Ans: 385.714

Sol:



$$C_{in} = 420 \text{ mg/l}$$

$$C_{out} = 75 \text{ mg/l}$$

$$Q = 4 \times 540 = 2160 \text{ lit/day}$$

$$\eta = \frac{C_{in} - C_{out}}{C_{in}} \times 100 = \frac{420 - 75}{420} \times 100$$

$$= 82.142\%$$

$$\eta = 100\%$$

$$C_{mix} = \frac{(Q - Q_B)C_{out} + Q_B C_B}{Q}$$

$$75 = \frac{(Q - Q_B) \times 0 + Q_B \times 420}{2160} \Rightarrow Q_B$$

$$= 385.714 \text{ lit/day}$$

Flow that can be by passed = 385.714
Lit/day

11. Refer to ESE - Volume II(Objective) Book

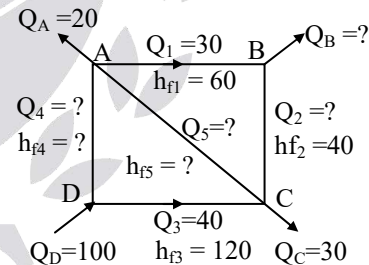
12. Refer to ESE - Volume II(Objective) Book

13. Refer to ESE - Volume II(Objective) Book

Chapter- 9
Distribution System

03.

Sol:



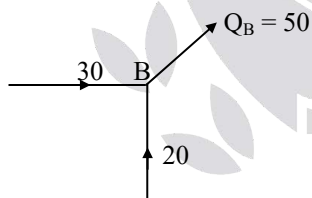
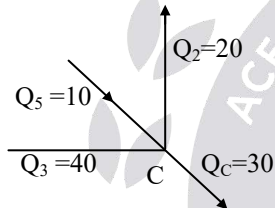
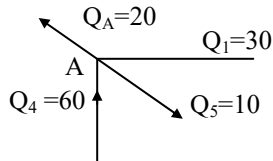
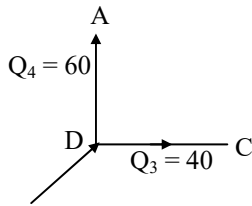
Unknown

$$Q_2 = ?$$

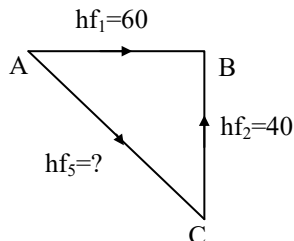
$$Q_4 = 60$$

$$Q_5 = 10$$

$$Q_B = ?$$



Consider loop ABCA



$$\sum H_{ABCA} : 0$$

$$+hf_1 - hf_2 - hf_3 = 0$$

$$+60 - 40 - hf_3 = 0$$

$$hf_3 = 20$$

06. Refer to ESE – Volume II(Objective)
Book

07. Refer to ESE – Volume II(Objective)
Book

08. Refer to ESE – Volume II(Objective)
Book

09. Refer to ESE – Volume II(Objective)
Book

10. Refer to ESE – Volume II(Objective)
Book

11. Ans: (c)

Sol: Water demand at 9th hour = 6.1 ML/hour

Water supply at constant rate = 1.5 m³/sec

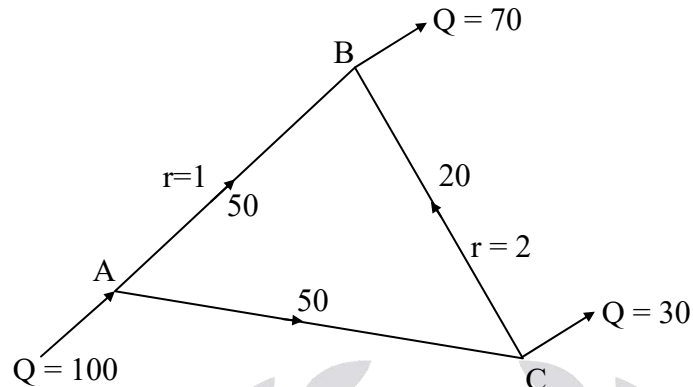
Water augmented from a storage reservoir in

ML/hour is

$$\frac{1.5 \times (1000) \times (60 \times 60)}{10^6} = 5.4 \text{ ML/ hour}$$



12. Ans: 0.615



$$h_f = r \cdot Q^{1.8}$$

$$\Sigma H_{ABCA} = 0$$

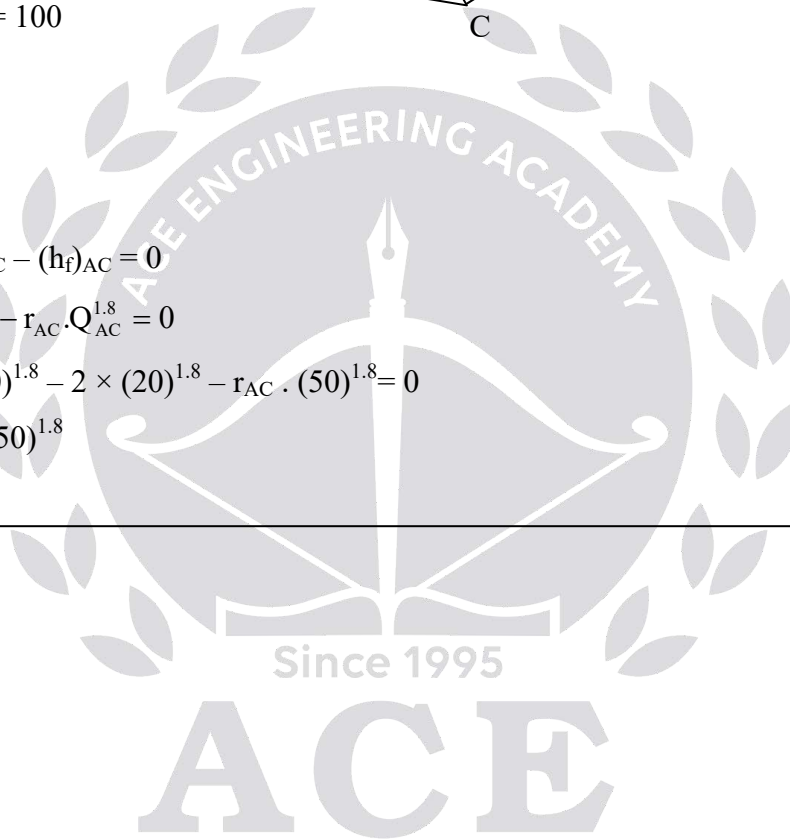
$$(h_f)_{AB} - (h_f)_{BC} - (h_f)_{AC} = 0$$

$$rQ_{AB}^{1.8} - rQ_{BC}^{1.8} - r_{AC} \cdot Q_{AC}^{1.8} = 0$$

$$1 \times (50)^{1.8} - 2 \times (20)^{1.8} - r_{AC} \cdot (50)^{1.8} = 0$$

$$703 = r_{AC} \times (50)^{1.8}$$

$$r_{AC} = 0.615$$





Waste Water Engineering

Chapter- 1 Introduction to Waste Water Engineering and Estimation of DWF & WWF

Class Room Practice Solutions

01. Ans: (b)

Sol: Storm's which occurs over catchment, if the duration of storm is not given (while calculating storm water discharge resulting from the catchment) calculating time of concentration is assumed as duration of storm.

02. Ans: (a)

Sol:

Area A = 16 Ha, R = 50 mm/hr

$$I = \frac{\sum A_i \times I_i}{A}$$

$$I = \frac{0.4 \times 0.8 + 0.3 \times 0.2 + 0.3 \times 0.1}{1}$$

$$= 0.41$$

$$Q = \frac{\text{AIR}}{360} = \frac{16 \times 0.41 \times 50}{360}$$

$$= 0.91 \text{ cumecs}$$

03. Ans: 0.1736 m³/sec, 2.015 m³/sec

Sol: Population = 1,00,000

$$Q_{\text{DWF}} = \text{Population} \times \text{percapita} \times \text{factor}$$

$$= 1,00,000 \times 200 \times 0.75$$

$$= 15 \times 10^6 \text{ lpcd} = 15 \text{ MLD}$$

$$= 0.1736 \text{ m}^3/\text{sec}$$

$$Q_{\text{WWF}} = \frac{\text{AIR}}{360}$$

$$R = \frac{25.4a}{t_c + b} = \frac{25.4 \times 40}{50 + 20}$$

$$= 14.51 \text{ mm/hr}$$

$$= \frac{100 \times 0.5 \times 14.51}{360}$$

$$= 2.015 \text{ m}^3/\text{sec}$$

04. Ans: 2.508 m³/sec

Sol: P = 40000; A = 75 ha

I = 0.70; Factor = 0.70

$$Q_{\text{DWF}} = \text{Population} \times \text{rate of flow} \times \text{factor}$$

$$Q_{\text{DWF}} = 40000 \times 120 \times 0.70$$

$$= 0.0388 \text{ m}^3/\text{sec}$$

$$R = \frac{25.4 \times 40}{40 + 20} = 16.93 \text{ mm/hr}$$

$$Q_{\text{WWF}} = \frac{\text{AIR}}{360} = \frac{75 \times 0.70 \times 16.93}{360}$$

$$Q_{\text{WWF}} = 2.47 \text{ m}^3/\text{sec}$$

$$\text{Combined discharge} = 0.0388 + 2.470$$

$$= 2.5088 \text{ m}^3/\text{sec}$$



05. Ans: 0.323 m³/sec

Sol: A = 1 km² = 100 ha

P = 1000 no/ha

For 100 ha, P = 100,000

Rate of flow = 200 lpcd

Factor = 0.80

I = 1

$$R = \frac{1.2 \times 10}{24} = 0.5 \text{ mm/hr}$$

$$Q_{\text{DWF}} = \frac{100000 \times 200 \times 0.80 \times 10^{-3}}{24 \times 3600}$$

$$Q_{\text{DWF}} = 0.185 \text{ m}^3/\text{sec}$$

$$Q_{\text{WWF}} = \frac{\text{AIR}}{360} = \frac{100 \times 1 \times 0.5}{360}$$

$$Q_{\text{WWF}} = 0.138 \text{ m}^3/\text{sec}$$

$$\begin{aligned} Q_{\text{Design}} &= Q_{\text{DWF}} + Q_{\text{WWF}} \\ &= 0.185 + 0.138 \\ &= 0.323 \text{ m}^3/\text{sec} \end{aligned}$$

06. Ans: 1.61 m³/sec

Sol: Given Area (A) = 50 ha

Impression factor (I) = 0.8

$$\therefore Q = \frac{\text{AIR}}{360} = \text{m}^3/\text{sec}$$

$$R = \frac{25.4 \times a}{t + b}$$

$$t = (10 \text{ min}) + \left(\frac{2400}{1} \right) \times \frac{1}{60} \text{ min}$$

$$t = 50 \text{ min}$$

as t > 20, a = 40, b = 20

$$\therefore R = \frac{25.4 \times 40}{50 + 20} = 14.514 \text{ m/hr}$$

$$\therefore Q = \frac{50 \times 0.8 \times 14.514}{360}$$

$$Q = 1.612 \text{ m}^3/\text{sec}$$

**08. Refer to ESE - Volume II(Objective)
Book**

**Chapter- 2
Design of Sewers**

01. Ans: (b)

02. Ans: 1.315 m

A = 150 Ha

Population = 50, 000

Maximum permissible velocity = 3.2
m/s

t_e = time of entry = 5 min

t_f = time of flow = 20 min

Rate of water supply = 270 lit/d

I = 0.45

Factor = 0.75

$$Q_{\text{DWF}} = \text{Population} \times \text{Per capita water supply} \times \text{factor}$$

$$= 50,000 \times 270 \times 0.75$$

$$= 10.125 \text{ MLD}$$

$$= 0.117 \text{ m}^3/\text{s}$$



$$Q_{WWF} = \frac{\text{AIR}}{360}$$

$$t_c = t_e + t_f = 5 + 20 = 25 \text{ min}$$

$$R = \frac{25.4a}{t_c + b}$$

$$= \frac{25.4 \times 40}{25 + 20}$$

$$= 22.57 \text{ mm/hr}$$

$$Q_{WWF} = \frac{150 \times 0.45 \times 22.57}{360}$$

$$= 4.23 \text{ m}^3/\text{s}$$

$$Q = Q_{DWF} + Q_{WWF} = 0.117 + 4.23$$

$$= 4.35 \text{ m}^3/\text{s}$$

$$Q = AV$$

$$4.35 = \frac{\pi}{4} d^2 \times 3.2$$

$$D = 1.315 \text{ m}$$

03. Ans: (c)

$$\text{Sol: } V = \frac{1}{n} (R)^{2/3} S^{1/2}$$

The velocity of flowing full and flowing half will be same

$$V = 1 \text{ m/sec}$$

04. Ans: 1 in 449

$$\text{Sol: Dia} = 45 \text{ cm} = 0.45 \text{ m}$$

$$\text{Population} = 30000$$

$$Q_{\text{design}} = 3.5 Q_{DWF}$$

$$n = 0.012$$

$$\text{Factor} = 0.80$$

$$\text{Rate of water supply} = 150 \text{ lpcd}$$

$$S = ?$$

$$Q_{DWF} = \text{Population} \times \text{per capita water supply} \times \text{factor}$$

$$Q_{DWF} = \frac{30000 \times 150 \times 0.80}{24 \times 10^3 \times 60 \times 60}$$

$$Q_{DWF} = 0.0416 \text{ m}^3/\text{sec}$$

$$Q_{\text{design}} = 3.5 \times 0.0416$$

$$= 0.1456 \text{ m}^3/\text{sec}$$

$$\text{For Running full } A = \frac{\pi}{4} D^2 \text{ \& } R = \frac{D}{4}$$

$$Q_{\text{design}} = A \cdot V$$

$$= \frac{\pi}{4} D^2 \times \frac{1}{n} \times (R)^{2/3} \times (S)^{1/2}$$

$$0.1456 = \frac{\pi}{4} \times (0.45)^2 \times \frac{1}{0.012} \times \left(\frac{0.45}{4}\right)^{2/3} \times (S)^{1/2} S$$

$$= 0.0022$$

$$S = \frac{1}{448.5} \approx \frac{1}{449}$$

05. Ans: 1.353 m³/sec

Sol:

$$d = 1.25 \text{ m}$$

$$S = \frac{1}{360}, n = 0.011$$

$$Q = ?$$

$$\text{for Half-full, } A = \frac{\pi}{8} D^2 \text{ \& } R = \frac{D}{4}$$

$$Q = A \cdot V = \frac{\pi}{8} D^2 \times \frac{1}{n} (R)^{2/3} (S)^{1/2}$$

$$Q = \frac{\pi}{8} \times (1.25)^2 \times \frac{1}{0.011} \times \left(\frac{1.25}{4}\right)^{2/3} \times \left(\frac{1}{360}\right)^{1/2}$$

$$Q = 1.35 \text{ m}^3/\text{sec}$$



06. Ans: 0.656 m/sec, 1 in 2160

Sol: $V_{self} = ?$

Dia of sand particles $d = 1 \text{ mm}$

$$S = 2.65$$

$$K = 0.1$$

$$f = 0.03$$

$$n = 0.013$$

$$V_{self} = \sqrt{\frac{8K}{f}(S-1)gd}$$

$$V_{self} = \sqrt{\frac{8 \times 0.1}{0.03}(2.65-1) \times 9.81 \times 1 \times 10^{-3}}$$

$$V_{self} = 0.656 \text{ m}^3/\text{sec}$$

$$V_{self} = V = \frac{1}{n} \cdot (R)^{2/3} (S)^{1/2}$$

$$0.656 = \frac{1}{0.013} \cdot \left(\frac{1}{4}\right)^{2/3} (S)^{1/2}$$

$$S = 4.63 \times 10^{-4} = \frac{1}{2159}$$

$$S = 1 \text{ in } 2159 \approx 1 \text{ in } 2160$$

07. Ans: 0.36 m, 0.027 m³/sec, 0.43 m/sec

Sol: Dia of sewer $D = ?$

$$n = 0.013$$

$$Q = 0.05 \text{ m}^3/\text{sec}$$

$$S = 1 \text{ in } 1000$$

$$\text{for Flow full, } A = \frac{\pi}{4} D^2 \text{ \& } R = \frac{D}{4}$$

$$Q = A \cdot V$$

$$Q = \frac{\pi}{4} D^2 \frac{1}{n} (R)^{2/3} (S)^{1/2}$$

$$0.05 = \frac{\pi}{4} D^2 \frac{1}{0.013} \left(\frac{D}{4}\right)^{2/3} \left(\frac{1}{1000}\right)^{1/2}$$

$$D = 0.36 \text{ m}$$

If the flow were at 0.60 depth

$$d = 0.60 D$$

$$q = ?$$

$$V = ?$$

$$\frac{d}{D} = \frac{0.6D}{D} = 0.60$$

d/D	q/Q	v/V
0.60	0.54	0.88

$$\frac{q}{Q} = 0.54$$

$$q = 0.54 \times 0.05 = 0.027 \text{ m}^3/\text{sec}$$

$$\frac{v}{V} = 0.88$$

$$V = 0.88 \times \frac{1}{n} (R)^{2/3} (S)^{1/2}$$

$$V = 0.88 \times \frac{1}{0.013} \left(\frac{0.36}{4}\right)^{2/3} \left(\frac{1}{1000}\right)^{1/2}$$

$$V = 0.43 \text{ m/sec}$$

08. Ans: (a)

Sol: Slope = $\frac{1}{400}$

$$V = 0.7 \text{ m/s}$$

$$\text{dia of sewer} = 600 \text{ mm}$$

$$\text{slope} = \frac{1}{200}$$

$$V = ?$$

$$V = \frac{1}{n} (R)^{2/3} (S)^{1/2} \quad R = \frac{D}{4}$$

$$R = \frac{0.6}{4}$$



$$\frac{1}{n} = \frac{V}{(R)^{2/3} (S)^{1/2}}$$

$$\frac{1}{n} = \left[\frac{V}{(R)^{2/3} (S)^{1/2}} \right]_{\text{full}} = \left[\frac{V}{(R)^{2/3} (S)^{1/2}} \right]_{\text{half}}$$

$$= \left[\frac{0.7}{\left(\frac{0.3}{4}\right)^{2/3} \left(\frac{1}{400}\right)^{1/2}} \right]_{\text{full}} = \left[\frac{V}{\left(\frac{0.6}{4}\right)^{2/3} \left(\frac{1}{200}\right)^{1/2}} \right]_{\text{half}}$$

$$V = 1.59 \text{ m/s}$$

09. Ans: (c)

Sol: Diameter of sewer = 300 mm = 0.30 m

$$S = \frac{1}{280}$$

$$q = 1728 \text{ m}^3 / \text{day}$$

$$n = 0.015$$

Depth of flow = ?

Velocity of flow $v = ?$

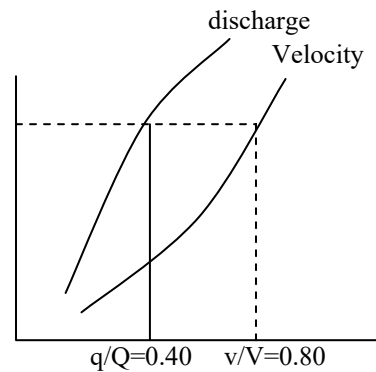
$Q = A \cdot V \rightarrow$ flow full

$$Q = \frac{\pi}{4} D^2 \frac{1}{n} \left(\frac{D}{4}\right)^{2/3} (S)^{1/2}$$

$$Q = \frac{\pi}{4} \times (0.30)^2 \times \frac{1}{0.015} \times \left(\frac{0.30}{4}\right)^{2/3} \times \left(\frac{1}{280}\right)^{1/2}$$

$$Q = 0.05 \text{ m}^3/\text{sec} = 4320 \text{ m}^3/\text{day}$$

$$\frac{q}{Q} = \frac{1728}{4320} = 0.40$$



$$\text{at } \frac{q}{Q} = 0.40$$

$$\frac{d}{D} = 0.50$$

$$\text{Depth of flow} = 0.50D = 0.5 \times 0.30 = 0.15 \text{ m} = 150 \text{ mm}$$

$$\text{at } \frac{d}{D} = 0.5$$

$$\frac{v}{V} = 0.8$$

$$V = 0.80V = 0.80 \times \frac{1}{n} \cdot (R)^{2/3} \cdot (S)^{1/2}$$

$$V = 0.80 \times \frac{1}{0.015} \times \left(\frac{0.30}{4}\right)^{2/3} \times \left(\frac{1}{280}\right)^{1/2}$$

$$V = 0.568 \text{ m/sec}$$

10. Ans: (c)

Sol:

$$D = 300 \text{ mm} ;$$

$$q = 1728 \text{ m}^3/\text{day} ;$$

$$n = 0.015 ;$$

$$S = 1/280$$

To find 'Q'



$$Q = A.V = \frac{\pi}{4} \cdot D^2 \times \frac{1}{n} \cdot R^{2/3} \cdot S^{1/2}$$

$$= \frac{\pi}{4} \cdot (0.3)^2 \times \frac{1}{0.015} \times \left(\frac{0.3}{4}\right)^{2/3} \times \left(\frac{1}{280}\right)^{1/2}$$

$$= 0.05 \text{ m}^3/\text{sec}$$

$$= 4320 \text{ m}^3/\text{day}$$

$$\therefore \frac{q}{Q} = \frac{1728}{4320} = 0.4$$

For $\frac{q}{Q} = 0.4$; from the graph (given).

$$\frac{d}{D} = 0.5$$

For $\frac{d}{D} = 0.5$, the $\frac{v}{V} = 0.8$

$$\therefore \frac{d}{D} = 0.5$$

$$\Rightarrow d = 0.5 \times 0.3 = 150 \text{ mm}$$

$$\therefore \frac{q}{V} = 0.8$$

$$q = 0.8 \times 0.708 = 0.57 \text{ m/sec}$$

11. Refer to ESE - Volume II(Objective)
Book
12. Refer to ESE - Volume II(Objective)
Book
13. Refer to ESE - Volume II(Objective)
Book
14. Refer to ESE - Volume II(Objective)
Book
15. Refer to ESE - Volume II(Objective)
Book

16. Refer to ESE - Volume II(Objective)
Book

17. Ans: (c)

$$\text{Sol: } \left(\frac{D}{2}\right)^2 = \left(\frac{D}{4}\right)^2 + x^2$$

$$x^2 = \frac{D^2}{16} - \frac{D^2}{4}$$

$$x = \frac{\sqrt{3}D}{4}$$

$$\sin\theta = \frac{x}{\frac{D}{2}}$$

$$= \frac{\frac{\sqrt{3}}{4}D}{\frac{D}{2}}$$

$$= \frac{\sqrt{3}}{2}$$

$$\theta = 60^\circ$$

Total angle @ $\theta = 120^\circ$

$$360^\circ \rightarrow 2\pi r$$

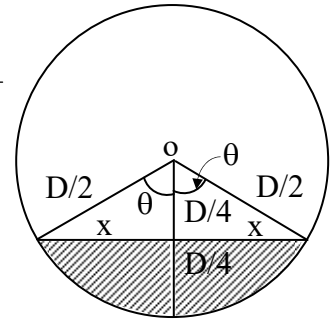
$$120^\circ \rightarrow ?$$

$$? = \frac{2\pi r \times 120}{360}$$

$$? = \frac{2\pi r}{3}$$

$$= \frac{2\pi \times \frac{D}{2}}{3}$$

$$\text{Wetted perimeter} = \frac{\pi D}{3}$$





Chapter- 3
Characteristics of Sewage

01. Ans: 212.19 mg/lit

Sol: Ultimate BOD $L_0 = ?$

$$6 \text{ ml} \rightarrow \text{Waste} \rightarrow D_0 = 0$$

$$294 \text{ ml} \rightarrow \text{distilled} \rightarrow D_0 = 8.6 \text{ mg/l}$$

$$(D_0)_{\text{Final}} = 5.4 \text{ mg/l}$$

$$K(\text{base } e) = 0.25 \text{ d}^{-1}$$

$$(D_0)_{\text{Initial}} = \frac{V_D(D_0)_D + V_S(D_0)_S}{V_D + V_S}$$

$$= \frac{294 \times 8.6 + 6 \times 0}{294 + 6}$$

$$(D_0)_I = 8.428 \text{ mg/l}$$

$$y_5^{20^\circ\text{C}} = [D_0]_I - (D_0)_F \times D.F$$

$$y_5^{20^\circ\text{C}} = [8.428 - 5.4] \times \frac{300}{6} = 151.4 \text{ mg/l}$$

$$5 \text{ day BOD at } 20^\circ\text{C } y_5^{20^\circ\text{C}}$$

$$y_t^{T^\circ\text{C}} = L_0(1 - e^{-K_t \times t})$$

$$y_t^{20^\circ\text{C}} = 151.4 = L_0(1 - e^{-K_{20} \times t})$$

$$151.4 = L_0(1 - e^{-0.25 \times 5})$$

$$L_0 = \text{Ultimate BOD 'L}_0' = 212.19 \text{ mg/l}$$

02. Ans: (d)

$$\text{Sol: } 5\% \text{ dilution of sample} = \frac{100}{5} = 20$$

$$= \frac{300}{15} = 20$$

$$(D_0)_F = 3.80 \text{ mg/l}, (D_0)_{\text{blank}} = 8.80 \text{ mg/l}$$

$$(D_0)_S = 0.8 \text{ mg/l}$$

$$(D_0)_I = (D_0)_{\text{mixer}} = \frac{V_o(D_0)_o + V_s(D_0)_s}{V_o + V_s}$$

$$= \frac{285 \times 8.8 + 0.8 \times 15}{285 + 15} = 8.4 \text{ mg/l}$$

$$y_5^{20} = [(D_0)_I - (D_0)_F] DF$$

$$= (8.4 - 3.80) \times 20 = 92 \text{ mg/l}$$

03. Ans: (c)

Sol: Fail in finding the BOD of waste water

04. Ans: 90 mg/l

Sol: $y_5^{30^\circ\text{C}}$ = sewage sample = 110 mg/l,

$$K_{D(20)} = 0.1/\text{day (base 10)}$$

$$y_5^{30^\circ\text{C}} = L_0(1 - e^{-K_t t})$$

$$y_5^{20^\circ\text{C}} = ?$$

$$K_{20} \text{ (base 10)} = 0.1 \text{ d}^{-1}$$

$$= 2.3 \times 0.1$$

$$= 0.23 \text{ d}^{-1} \text{ (base } e)$$

$$L_0 = \frac{y_t^{T^\circ\text{C}}}{(1 - e^{-k_t t})} = \frac{y_5^{30^\circ\text{C}}}{(1 - e^{-k_{30} t})}$$

$$y_5^{30} = L_0(1 - e^{-K_{30} \times t})$$



$$K_T = K_{20}(1.047)^{T-20}$$

$$K_{30} = 0.23(1.047)^{30-20}$$

$$= 0.364d^{-1}$$

$$110 = L_o(1 - e^{-0.364 \times 5})$$

$$L_o = 131.78 \text{ mg/l}$$

$$y_5^{20} = L_o(1 - e^{-K_{20} \times 5})$$

$$= 131.78(1 - e^{-0.23 \times 5}) = 90 \text{ mg/l}$$

05. Ans: 246.36 mg/l

Sol: $y_1^{30^\circ C} = 110 \text{ mg/l}$, $y_5^{20^\circ C} = ?$

$$K_{(20)} = 0.1d^{-1}$$

$$= 0.23d^{-1} \text{ (base e)}$$

$$y_1^{30^\circ C} = L_o(1 - e^{-0.364 \times 1})$$

$$110 = L_o(1 - e^{-0.364 \times 1})$$

$$L_o = 360.5 \text{ mg/l}$$

$$K_{30} = 0.23(1.047)^{30-20} = 0.364d^{-1}$$

$$y_5^{20} = L_o(1 - e^{-K_{20} \times t})$$

$$= 360.5(1 - e^{-0.23 \times 5}) = 246.36 \text{ mg/l}$$

06. Ans: 304000

Sol: $Q = 80 \times 10^6 \text{ l/d}$, $y = 285 \text{ mg/l}$,

compute daily 5 day O_2 demand

$$\text{Total strength of waste} = Q \times y$$

$$= 80 \times 285$$

$$= 22800 \text{ kg/day}$$

$$\text{Population equivalent} = \frac{Q \times y}{\text{per capita BOD}}$$

$$= \frac{22800}{75 \times 10^{-3}} = 304000$$

$$\text{Population equivalent} = 304000 \text{ persons}$$

07. Ans: 93.72%

Sol: $S_r = 100(1 - 0.794^t)$

$$= 100(1 - 0.794^{12})$$

$$S_r = 93.72\%$$

08. Ans: 1%

Sol: $BOD_5 = 600 \text{ mg/l}$,

$$K = 0.23/d \text{ (base e)}; K = 0.23d^{-1}, L_o = ?$$

BOD_u remain unoxidised after 20 days = ?

$$y_5^{20^\circ C} = L_o(1 - e^{-K \cdot t})$$

$$600 = L_o(1 - e^{-0.23 \times 5})$$

$$L_o = 878.01 \text{ mg/l}$$

$$L_{20} = L_o e^{-Kt}$$

$$= 878.01 \times e^{Kt}$$

$$= 878.01 \times e^{-0.23 \times 20}$$

$$= 8.82 \text{ mg/l}$$

$$\% \text{ of unoxidised} = \frac{8.82}{878.01} \times 100 = 1\%$$



09. Ans: (a)

Sol:

Waste water Volume ml	Initial D_0 mg/l	D_0 after 50 day mg/l
5	9.2	6.9
10	9.1	4.4
50	8.4	0.0

$$\text{Dilution factor} = \frac{300}{5} = 60$$

$$y_5^{20} = [(D_0)_I - (D_0)_F] \times DF$$

$$= [9.2 - 6.9] \times 60$$

$$= 138 \text{ mg/l}$$

$$y_5^{20} = [9.1 - 4.4] \times \frac{300}{10} = 141 \text{ mg/l}$$

$$\text{BOD}_{\text{avg}} = \frac{138 + 141}{2} = 139.5 \text{ mg/l}$$

10. Ans: (c)

Sol: $y_5^{20} = L_0(1 - e^{-Kt})$

$$K = 0.01 \text{ h}^{-1} \text{ (base e)}$$

$$= 0.01 \times 24 \text{ d}^{-1} = 0.24 \text{ d}^{-1}$$

$$190 = L_0(1 - e^{-0.24 \times 5})$$

$$L_0 = \frac{190}{(1 - e^{-0.24 \times 5})} = 271.89 \text{ mg/l}$$

11. Ans: (d)

Sol: $y_5^{20^\circ\text{C}} = 180 \text{ mg/l}$

$$k_{20} = 0.18 \text{ d}^{-1}$$

$$k_T = k_{20} (1.047)^{T-20}$$

= to exert same BOD in 2.5 days

$$y_5^{20^\circ\text{C}} = y_{2.5}^{T^\circ\text{C}} = 180 \text{ mg/l}$$

$$l_0(1 - e^{-k_{20} \times 5}) = l_0(1 - e^{-k_T \times 2.5})$$

$$k_{20} \times 5 = k_{20} (1.047)^{T-20} \times 2.5$$

$$(1.047)^{T-20} = 2$$

$$(T - 20) \ln 1.047 = \ln 2$$

$$T = 35^\circ\text{C}$$

12. Ans: (c)

Sol: $\text{BOD}_3 = 75 \text{ mg/l}$, $K = 0.345 \text{ d}^{-1}$ (base e)

$$\text{BOD} = 10 \text{ days} = ?$$

$$y_3^{20} = L_0(1 - e^{-0.345 \times 3})$$

$$L_0 = 116.31 \text{ mg/l}$$

$$L_t = 116.31(1 - e^{-0.345 \times 10})$$

$$L_t = 112.61 \text{ mg/l}$$

$$L_0 - L_t = 116.31 - 112.61 = 3.7 \text{ mg/l}$$

14. Ans: (b)

Refer to ESE Volume-II (objective)
Book



16. Ans: (b)

$$\begin{aligned} \text{Sol: } y_5^{20^\circ\text{C}} &= [(DO)_I - (DO)_F] \times DF \\ &= [8.5 - 5.5] \times \frac{100}{2} = 150 \text{ mg/l} \end{aligned}$$

18. Ans: (c)

$$\text{Sol: } y = 162 \text{ mg/l}$$

$$Q = 1000 \text{ m}^3/\text{day}$$

$$Q = 1000 \times 1000 \text{ lpcd} = 1 \text{ MLD}$$

$$\text{Per capita BOD} = 80 \text{ gm/capita}$$

Population equivalent

$$= \frac{\text{total BOD}}{\text{per capita BOD}}$$

$$= \frac{Q y}{\text{Per capita BOD}} = \frac{1 \times 162}{80 \times 10^{-3}} = 2025$$

19. Ans: (b)

$$\text{Sol: } [(DO)_I] = 8 \text{ mg/l}, (DO)_F = 2 \text{ mg/l}$$

$$\text{Dilution factor} = \frac{300}{2} = 150 \text{ ml}$$

$$\begin{aligned} \text{5 days BOD} &= [(DO)_I - (DO)_F] \times D.F. \\ &= (8-2) \times 150 \\ &= 900 \text{ mg/l} \end{aligned}$$

20. Ans: (a)

Refer to ESE Volume-II (objective)
Book

21. Ans: (c)

$$\text{Sol: } y_5^{20} = 250 \text{ mg/l}, T = 30^\circ\text{C}, t = ?,$$

$$y_5^{30} = 250 \text{ mg/l}$$

$$y_5^{20} = y_5^{30}$$

$$L_o(1 - e^{-K_{20} \times 5}) = L_o(1 - e^{-K_{30} \times t})$$

$$K_{20} \times 5 = K_{30} \times t$$

$$K_{20} \times 5 = K_{20}(1.047)^{30-20} \times t$$

$$t = \frac{5}{(1.047)^{10}} = 3.158 = 3.3 \text{ days}$$

23. Ans: (a)

$$\text{Sol: } y_5^{20^\circ\text{C}} = y_3^{27^\circ\text{C}} = y_4^{30^\circ\text{C}}$$

$$L_o(1 - e^{-K_{20} \times 5}) = L_o(1 - e^{-K_{27} \times 3}) = L_o(1 - e^{-K_{30} \times 4})$$

$$K_{20} \times 5 = K_{20} \times (1.047)^{27-20} \times 3 = K_{20} (1.047)^{30-20} \times 4$$

$$5 \simeq 4.13 \simeq 6.33$$

5 days 20°C BOD equal to 3 days 27°C BOD

25. Ans: 128.1 mg/l

$$\text{Sol: } y_5^{20^\circ} = ?$$

$$y_7^{20^\circ\text{C}} = 150 \text{ mg/l}$$

$$K = 0.23 \text{d}^{-1} \text{ (base e)}$$

$$150 = L_o(1 - e^{-0.23 \times 7})$$

$$L_o = 187.47 \text{ mg/l}$$

$$y_5^{20^\circ\text{C}} = 187.47(1 - e^{-0.23 \times 5})$$

$$y_5^{20^\circ} = 128.11 \text{ mg/l}$$



26. Ans: (c)

Sol: $L_o = 20 \text{ mg/l}$

$$K = 0.15 \text{ d}^{-1}$$

$$\% \text{ BOD exerted in 7days} = \frac{y_7}{L_o} \times 100$$

$$= \frac{L_o [1 - e^{-Kt}]}{L_o} \times 100$$

$$= \frac{20 [1 - e^{-0.15 \times 7}]}{20} \times 100$$

$$= 65\%$$

$$\% \text{ BOD remaining after 7days} = \frac{L_7}{L_o} \times 100$$

$$= \frac{L_o e^{-kt}}{L_o} \times 100$$

$$= \frac{20 \times e^{-0.15 \times 7}}{20} \times 100$$

$$= 35\%$$

27. Refer to ESE Volume-II (objective)
Book

28. Refer to ESE Volume-II (objective)
Book

29. Refer to ESE Volume-II (objective)
Book

30. Refer to ESE Volume-II (objective)
Book

31. Refer to ESE Volume-II (objective)
Book

Chapter- 4 Treatment of Sewage

02. Ans: (d)

Sol: $H = 0.8 \text{ m}$, $Q = 720 \text{ m}^3/\text{hr} = 70 \text{ m}^3/\text{min}$

$$L = 12 \text{ m}, B = 1.50 \text{ m}$$

$$\text{Surface loading rate} = \frac{Q}{\text{surface area}}$$

$$= \frac{720}{12 \times 1.50} = 40 \text{ m}^3/\text{hr}$$

$$D.T = \frac{\text{Volume of G.C}}{Q} = \frac{L \times B \times H}{Q}$$

$$= \frac{12 \times 1.5 \times 0.8 \times 60}{720} = 1.2 \text{ min}$$

04. Ans: (b)

Sol: $Q = 3 \text{ m}^3/\text{sec}$, cross section of grit chamber
=?

$$\text{Cross sectional area (B.H)} = \frac{Q}{V_H}$$

$$A = \frac{3}{0.3} = 10 \text{ m}^2$$

05. Ans: (b)

Sol: $G = 2.70$

$$d = 0.21 \text{ mm}$$

$$V_s = ?$$

$$v = 1 \times 10^{-2} \text{ cm}^2/\text{sec} = 1 \times 10^{-6} \text{ m}^2/\text{sec}$$



For laminar flow condition

$$V_s = \frac{g(S-1)d^2}{18\nu}$$

$$V_s = \frac{9.81 \times (2.70 - 1) \times (0.21 \times 10^{-3})^2}{18 \times 1 \times 10^{-6}}$$

$$V_s = 0.04089 \text{ m/sec} = 4.089 \text{ cm/sec}$$

06. Ans: (b)

Sol: L = 7.5 m; H = 0.9m

$$V_H = 0.3 \text{ m/sec}$$

$$\begin{aligned} \nu &= \frac{\mu}{\rho} = \frac{1.002 \times 10^{-3}}{1000} \\ &= 1.002 \times 10^{-6} \text{ m}^2/\text{sec} \end{aligned}$$

$$\text{For } \eta = 100\%, \frac{L}{V_H} = \frac{H}{V_s}$$

$$V_s = 0.036 \text{ m/sec}$$

$$V_s = \frac{g}{18} \left((s-1) \frac{d^2}{\nu} \right)$$

$$0.036 = \frac{9.8}{18} (2.5 - 1) \cdot \frac{d^2}{(1.002 \times 10^{-6})}$$

$$d = 0.21 \text{ mm}$$

07. Ans: (d)

Sol: Q = 5005 m³/d

$$V_0 = 35 \text{ m}^3/\text{m}^2/\text{d}$$

$$\text{Surface area} = \frac{Q}{V_0} = \frac{5005}{35}$$

$$\frac{\pi}{4} d^2 = 143$$

$$d = 13.5 \text{ m}$$

08. Refer to ESE – Volume II(Objective) Book

09. Refer to ESE – Volume II(Objective) Book

10. Refer to ESE – Volume II(Objective) Book

11. Refer to ESE – Volume II(Objective) Book

12. Refer to ESE – Volume II(Objective) Book

13. Refer to ESE – Volume II(Objective) Book



Chapter- 5
Activated Sludge Process

01. Ans: (a)

Sol: $y_i = 180 \text{ mg/l}$, $V_L = 550 \text{ gm of BOD per 1 cu.m of volume}$

$$Q = 50 \times 10^6 \text{ l/d} = 50 \text{ MLD}, V = ?$$

$$V.L.R. = \frac{Qy_i}{V}$$

$$550 \times 10^{-3} = \frac{50 \times 180}{V}$$

$$550 \times 10^{-3} \times V = 9000$$

$$V = 16363 \text{ m}^3$$

02. Ans: (d)

Sol: $Q = 50 \times 10^6 \text{ l/d} = 50 \text{ MLD}$, $y_i = 180 \text{ mg/l}$,

$$\frac{F}{M} = 0.5 \text{ d}^{-1}, X = 1800 \text{ mg/l}, V = ?$$

$$\frac{F}{M} = \frac{Qy_i}{VX}$$

$$0.5 = \frac{50,000 \times 180}{1800 \times V} \Rightarrow V = 10,000 \text{ m}^3$$

03. Ans: (a)

Sol: $X = 2000 \text{ mg/l}$

$$SVI = \frac{V}{X} = \frac{\text{Volume occupied in ml}}{\text{MLSS in gm}}$$

$$= \frac{176}{2000} = \frac{176}{2} = 88 \text{ ml/gm}$$

$$\frac{10^3}{10^3}$$

Common Data for Question Nos. 04 & 05

04. Ans: (c)

Sol: $Q = 35,000 \text{ m}^3/\text{d}$, $V = 10900 \text{ m}^3$,

$$y_1 = 250 \text{ mg/l}, y_e = 20 \text{ mg/l}$$

$$\text{MLSS} = 2500 \text{ mg/l}$$

$$\text{Aeration period} = \frac{V}{Q} = \frac{10,900}{35,000} = 7.47 \text{ hrs}$$

05. Ans: (b)

$$\text{Sol: } \frac{F}{M} = \frac{Q(y_i)}{VX}$$

$$= \frac{35000(250)}{10,900 \times 2500} \frac{\text{m}^3/\text{d}/(\text{mg}) \ln}{\text{m}^3/\text{mg/l}}$$

$$= 0.32 \text{ d}^{-1}$$

06. Ans: (c)

$$\text{Sol: } \eta_{\text{BOD}} = \frac{y_i - y_e}{y_i} \times 100$$

$$= \frac{250 - 20}{250} \times 100 = 92\%$$

07. Ans: (a)

$$\text{Sol: Sludge age } \theta_c = \frac{VX}{Q_w X_u + Q_e X_e}$$

$$= \frac{10900 \times 2500}{220 \times 9700 + (35000 - 220)30}$$

$$= 8.57 \text{ days}$$



08. Ans: (c)

Sol: $SVI = 88 \text{ ml/gm}$, $X_u = ?$

$$X_u = \frac{10^6}{SVI} = \frac{10^6}{88} = 11364 \text{ mg/l}$$

09. Ans: (c)

Sol: $X = 1000 \text{ mg/l}$, Volume = 200 ml

$$SVI = \frac{V}{X} = \frac{200}{1} = 200 \text{ ml/gm}$$

10. Ans: (d)

Sol: $V = 400 \text{ m}^3$, $X = 1000 \text{ mg/l}$

$$\begin{aligned} \text{Total amount of MLSS in aeration tank} &= VX \\ &= 400 \times 1000 \times (1000 \times 10^{-6}) = 400 \text{ kg} \end{aligned}$$

12. Ans: 6.3 hrs, 109.5, 0.33d⁻¹, 2054.3m³day

Sol: $L = 30 \text{ m}$, $B = 14 \text{ m}$, $H = 4.3 \text{ m}$

$$Q = 0.796 \text{ m}^3/\text{s} = 6877.44 \text{ m}^3/\text{day}$$

$$y_1 = 130 \text{ mg/l}$$

$$X = 2100 \text{ mg/l}$$

$$MLVSS = 1500 \text{ mg/l}$$

$$\text{Volume occupied} = 230 \text{ m}^3/\text{lit}$$

$$\begin{aligned} \frac{F}{M} &= \frac{Qy}{VX} \\ &= \frac{6877.44 \times 130}{1806 \times 1500} = 0.33 \text{ d}^{-1} \end{aligned}$$

$$DT = \frac{V}{Q} = \frac{1806}{6877.44} = 6.3 \text{ hrs}$$

$$SVI = \frac{230}{2.1} = 109.5 \text{ ml/day}$$

$$\frac{Q_r}{Q} = \frac{X}{\frac{10^6}{SVI} - X}$$

$$\begin{aligned} \frac{Q_r}{6877.4} &= \frac{2100}{\frac{10^6}{109.5} - 2100} \\ &= 2054.3 \text{ m}^3/\text{day} \end{aligned}$$

13. Ans: (c)

Sol: $X = 2800 \text{ mg/l}$ carried out 1 lit sample

$$V = 200 \text{ ml}$$

$$SVI = \frac{200}{2.8} = 71.4 \text{ ml/gm}$$

Common data for Q 14 & 15

14. Ans: (c)

Sol: Given,

$$Q = 500 \text{ m}^3/\text{h}$$

$$y_i = 150 \text{ mg/l}$$

$$y_e = 10 \text{ mg/l}$$

$$DT = 8 \text{ hours}$$

$$Q_C = 240 \text{ hours}$$

$$V = 4000 \text{ m}^3$$

$$X = 2000 \text{ mg/l}$$

$$\frac{F}{M} = \frac{Qy_i}{VX} = \frac{500 \times 150 \times 24}{4000 \times 2000}$$

$$\frac{F}{M} = 0.225 \text{ per day}$$



15. Ans: (c)

$$\text{Sol: } Q_c = \frac{\text{mass of solid reactors}}{\text{mass of solid wasted per day}}$$

$$Q_c = \frac{VX}{\text{mass of solid wasted per day}}$$

$$\text{Mass of solid wasted/day} = \frac{VX}{Q_c}$$

$$= \frac{4000 \times 2000}{240} \times 1000 \times \frac{1}{10^6}$$

$$= 800 \text{ kg/day}$$

16. Ans: (d)

$$\text{Sol: } X = 4000 \text{ mg/l} = 4 \text{ gm/l}$$

$$\text{Volume} = 200 \text{ m}^3$$

$$\text{SVI} = \frac{\text{Volume}}{X} = \frac{200}{4}$$

$$\text{SVI} = 50 \text{ m}^3/\text{gm}$$

17. Ans: (c)

Sol: MLSS normally kept any where between
1500- 3000 mg/l

19. Ans: i. (2000 m³)

ii. (4.8 hrs)

iii. (86.66%)

iv. 0.75 kg/day/m³

v. 600 kg/day

vi. 60 m³/day

vii. 100

viii. 0.428

ix. 4285.71 m³/day

Sol: Given:

$$\text{Flow rate (Q)} = 10,000 \text{ m}^3/\text{day}$$

$$\text{Inflow BOD (y}_i\text{)} = 150 \text{ mg/lit}$$

$$\text{Outflow BOD (y}_E\text{)} = 20 \text{ mg/lit}$$

$$\text{MLSS (X)} = 3,000 \text{ mg/lit}$$

We know

$$\frac{F}{M} = \frac{Qy_i}{VX}$$

$$VX = \frac{10,000 \times 150}{0.25} = 6 \times 10^6$$

(I) Volume of aeration tank

$$V = \frac{6 \times 10^6}{3 \times 10^3} \quad (\because X = 3000 \text{ mg/lit})$$

$$\therefore \text{Volume} = 2000 \text{ m}^3$$

(II) Aeration period = $\frac{2000}{10,000} \times 24$

$$= 4.8 \text{ hours}$$

(III) B.O.D removal efficiency

$$= \frac{y_i - y_E}{y_i} \times 100$$

$$= \frac{150 - 20}{150} \times 100$$

$$\eta = 86.66\%$$

(IV) Volumetric loading rate

$$V_L = \frac{Qy_i}{V} = \frac{10,000 \times 150}{2000} \times \frac{1000}{10^6}$$

$$= 0.75 \text{ kg/day/m}^3$$

(V) Mass of sludge wasted per day

$$\text{MCRT} = \theta_c = \frac{VX}{Q_w x_u + Q_e x_e}$$

$$10 = \frac{200 \text{ m}^3 \times 300 \text{ mg/L} \times \frac{100 \text{ L}}{\text{m}^3} \times \frac{1 \text{ kg}}{10^9 \text{ mg}}}{\text{mass of sludge wasted per day}}$$

$$\therefore \text{Mass of sludge wasted per day} = 600 \text{ kg/day}$$



(VI)

Volume of sludge wasted per day

$Q_w x_u + Q_e x_e =$ mass of sludge wasted per day

$Q_w(10,000) + (Q - Q_w)(0) = 600 \text{ kg/day}$

$$Q_w = \frac{600}{10,000} = 0.06 \text{ MLD}$$

$$Q_w = 0.06 \times \frac{10^6 \text{ L}}{1 \text{ mL}} \times \frac{1 \text{ m}^3}{1000 \text{ L}}$$

$$Q_w = 60 \text{ m}^3/\text{day}$$

(VII) $S.V.I = \frac{10^6}{X_w} = \frac{10^6}{10,000} = 100 \text{ ml/gm}$

$$S.V.I = 100$$

(VIII) $\frac{Q_R}{Q} = \text{Recycling ratio} = \frac{X}{X_w - X}$

$$\Rightarrow \frac{Q_R}{Q} = \frac{3000}{10000 - 3000} = 0.4285$$

(IX) \therefore Rate of return sludge

$$Q_R = 0.4285 \times 10,000$$

$$Q_R = 4285 \text{ m}^3/\text{day}$$

19. Refer to ESE – Volume II(Objective)
Book

20. Refer to ESE – Volume II(Objective)
Book

21. Refer to ESE – Volume II(Objective)
Book

22. Ans: (b)

Sol: Total BOD applied (loaded) = 968 kg/day

O_2 transfer capacity of aerator = 0.8 kg of

O_2 / HP.hr

Capacity of each aeration =

$$\frac{\text{Total } O_2 \text{ to be supplied}}{O_2 \text{ transfer capacity of aerator}}$$

$$= \frac{768 \text{ kg/hr}}{0.8}$$

$$= \frac{768}{24} \text{ kg/ Hp.hr}$$

Total O_2 to be supplied = total BOD

$$= 20 \text{ HP}$$

Chapter- 6
Trickling Filters

01. Ans: (c)

Sol: $y_i = 200 \text{ mg/l}$

$y_e = 40 \text{ mg/l}$

$$\eta = \frac{y_i - y_e}{y_i} \times 100$$

$$\eta = \frac{200 - 40}{200} \times 100 = 80\%$$

02. Ans: (b)

Sol: $OLR = 0.175 \text{ kg/m}^3/\text{day}$

$y_i = 150 \text{ mg/l}$

$y_e = ?$

$$\eta = \frac{100}{1 + 0.0044 \sqrt{\frac{Q \cdot y_i}{V \cdot F}}}$$



$$1 \text{ ha.m} = 10^4 \text{ m}^3$$

$$1 \text{ m}^3 = 10^{-4} \text{ ha. m}$$

$$\frac{Qy_i}{V} \text{ kg of BOD/day/ ha.m}$$

$$\text{OLR} = 0.175 \times 10^4 \text{ kg/ha.m/day}$$

$$\eta = \frac{150 - y_e}{150} \times 100$$

$$\frac{150 - y_e}{150} \times 100 = \frac{100}{1 + 0.0044 \sqrt{\frac{0.175 \times 10^4}{1}}}$$

$$y_e = 23.31 \text{ mg/l}$$

03. Ans: 2.14m, 5142.85m³,
84.45%, 23.3 mg/l

Sol: Q = 6 MLD

$$y_i = 150 \text{ mg/l}$$

$$\text{OLR} = 175 \text{ gm/m}^3/\text{day}$$

$$\text{SLR} = 2500 \text{ l/m}^2/\text{day}$$

Depth of TF = ?

Vol. of TF = ?

$$\eta = ?$$

$$y_e = ?$$

(a) Surface loading rate = $\frac{Q}{\text{surface area}}$

$$\frac{\pi}{4} \times d^2 = \frac{6 \times 10^6}{2500}$$

$$d = 55.27 \text{ m}$$

$$\text{organic loading Rate} = \frac{Q \cdot y_i}{V}$$

$$V = \frac{150 \times 6}{175 \times 10^{-3}}$$

$$V = 5142.85 \text{ m}^3$$

$$\text{Depth of TF} = \frac{\text{Vol. of TF}}{\text{surface area of TF}}$$

$$D = \frac{5142.85}{2400} = 2.14 \text{ m}$$

(b) $\text{OLR} = 175 \times 10^{-3} \times 10^4 \text{ kg/ha. m/day}$

$$\text{OLR} = 1750 \text{ kg/ha. m/day}$$

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

$$\eta = \frac{100}{1 + 0.0044 \sqrt{175 \times 10^{-3} \times 10^4}}$$

$$\eta = 84.45\%$$

(c) $\eta = \frac{y_i - y_e}{y_i} \times 100$

$$84.45 = \frac{150 - y_e}{150} \times 100$$

$$y_e = 23.32 \text{ mg/l}$$

04. Ans: 633 m³

Sol: Single stage TF

$$y_e = 20 \text{ mg/l}; y_i = 120 \text{ mg/l}$$

$$Q = 2200 \text{ m}^3/\text{day}$$

$$R = 4000 \text{ m}^3/\text{day}$$

$$V = ?$$

∴ Recirculation is there it is high rate TF

$$\frac{R}{I} = \frac{4000}{2200} = 1.81$$

$$F = \frac{1 + \frac{R}{I}}{\left(1 + 0.1 \frac{R}{I}\right)^2} = 2.017$$



$$Q = 2200 \text{ m}^3/\text{day} = 2.2 \text{ MLD}$$

$$\eta = \frac{y_i - y_e}{y_i} \times 100$$

$$\eta = \frac{120 - 20}{120} \times 100 = 83.33\%$$

$$83.33 = \frac{100}{1 + 0.0044 \sqrt{\frac{2.2 \times 120}{V \times 2.017}}}$$

$$V = 0.0633 \text{ ha. m}$$

$$V = 633 \text{ m}^3$$

05. Ans: (b)

Sol: If $\frac{R}{I} = 1$ then $F > 1$

$$\therefore F = \frac{1 + \frac{R}{I}}{\left(1 + 0.1 \frac{R}{I}\right)^2}$$

06 Ans: (b)

Sol: At the interface of media as the thickness of biofilm increases it leads to endogenous decay & anaerobic conditions.

07. Refer to ESE - Volume II(Objective) Book

Chapter- 7 Sludge Digestion

01. Ans: 17105.62 kg/day, 16.68m³/day

Sol: $Q = 4.5 \text{ MLD}$

$$\begin{aligned} \text{(i) Total dry solids} &= Q \times \text{suspended solids} \\ &= 4.5 \times 275 \\ &= 1237.5 \text{ kg/day} \end{aligned}$$

$$\text{Mass of sludge produced} = \frac{100}{(100 - P_1)} M$$

Solids concentration in sludge

$$= \frac{55}{100} \times 275 = 151.25 \text{ mg/l}$$

Total mass of dry solids produced/day

$$\begin{aligned} &= \frac{100}{(100 - \eta_c)} \times M \\ &= \frac{100}{(100 - 96)} \times 680.625 \\ &= 17015.625 \text{ kg/day} \end{aligned}$$

$$\text{(ii) } \frac{\rho_{\text{sludge}}}{\rho_w} = S_{\text{sludge}}$$

$$\rho_{\text{sludge}} = 1.02 \times 1000 = 1020 \text{ kg/m}^3$$

$$\rho_{\text{sludge}} = \frac{\text{mass of sludge}}{\text{Volume of sludge}}$$

$$1020 = \frac{17015.625}{\text{Volume of sludge}}$$

$$\begin{aligned} \text{Volume of sludge} &= \frac{17015.625}{1020} \\ &= 16.68 \text{ m}^3/\text{day} \end{aligned}$$



03. Ans: (c)

$$\text{Sol: } \frac{V_2}{V_1} = \frac{100 - P_1}{100 - P_2} = \frac{100 - 99}{100 - 96} = 0.25\%$$

% of reduction in volume = $100 - 25 = 75\%$

05. Ans: (d)

$$\text{Sol: } V_2 = \frac{100 - P_1}{100 - P_2} \times P = \frac{100 - 98}{100 - 96} \times P$$

$$= \frac{1}{2}(P) = \frac{P}{2}$$

Common Data for Question Nos. 07 & 08

07. Ans: (c)

Sol: Solid content = 2%

\therefore water content = 98%

$$\frac{100}{S_{\text{sludge}}} = \frac{\% \text{ water}}{S_{\text{water}}} + \frac{\% \text{ Solids}}{S_{\text{solids}}}$$

$$\frac{100}{S_{\text{sludge}}} = \frac{98}{1} + \frac{2}{2.2}$$

$$S_{\text{sludge}} = 1.011$$

$$\rho_{\text{sludge}} = 1.011 \times 1000 = 1011 \text{ kg/m}^3$$

08. Ans: (b)

Sol: After thickening $V_2 = \frac{V_1}{2}$

$$V_2 = \frac{(100 - P_1)V_1}{(100 - P_2)} \Rightarrow 100 - P_2 = 200 - 196$$

$$P_2 = 96\%$$

(\therefore Solid content is 4%)

12. Ans: 1.011, 1011 kg/m³

Sol: Given solids content = 2%

Let ρ_{solid} be the mass density of solids
Solids again contain 70% volatile & 30% of non-volatile

$$\therefore \text{we know } = \frac{100}{S_{\text{solids}}} = \frac{70}{S_{\text{volatile}}} + \frac{30}{S_{\text{non-volatile}}}$$

$$\Rightarrow \frac{100}{S_{\text{solids}}} = \frac{70}{2.2} + \frac{30}{2.7}$$

$$\Rightarrow S_{\text{solids}} = 2.329$$

$$\approx 2.4$$

Now let mass density of sludge as ρ_s and specific gravity as S_s

$$\therefore \frac{100}{S_s} = \frac{2}{S_{\text{solids}}} + \frac{98}{S_{\text{water}}}$$

$$\Rightarrow \frac{100}{S_s} = \frac{2}{2.4} + \frac{98}{1}$$

$$\Rightarrow S_s = 1.011$$

$$\rho_s = 1011 \text{ kg/m}^3$$

14. Refer to ESE – Volume II(Objective) Book

15. Ans: (c)

Sol: $P_1 = 94\%$

Solid content = 16%

$P_2 = 84\%$

Water content = $100 - 16 = 84\%$



$$V = \frac{100 - P_1}{100 - P_2} \times V_1$$

$$= \frac{100 - 94}{100 - 84} \times 14$$

$$= 5.25 \text{ m}^3$$

Chapter- 8 Septic Tanks

01. Ans: 6.32 × 3.16

Sol: No. of users = 200

Per capita DWF = 150 lpcd

DT = 24 hrs

liquid depth = 1.5 m

L/B = 2: 1

$Q = 200 \times 150 = 30 \text{ m}^3/\text{d}$

Volume = $Q \times DT$

$$= \frac{30}{24} \times 24 = 30 \text{ m}^3$$

$L \times B \times H = 2B \times B \times 1.5 = 30$

$B = 3.16 \text{ m}$

$L = 6.32 \text{ m}$

$L \times B = 6.32 \text{ m} \times 3.16 \text{ m}$

02. Ans: 0.6 m

Sol: Rate of sludge production

= 30 lit/person/year

Cleaning period = 2 yrs

Depth of sludge zone = ?

$Q_{\text{sludge}} = 30 \times 200 \times 10^{-3}$

= 6 m³/year

Volume = 6 × 2 = 12 m³

depth = $\frac{12}{6.32 \times 3.16} = 0.6 \text{ m}$

03. Ans: (a) 9.6 m³ (b) 12 m³

Sol: Population = 120

Per capita sewage flow = 150 lpcd

Size of septic tank = 4m × 2m

liquid depth = 1.5 m

Detention period = ?

$Q = 120 \times 150 = 18 \text{ m}^3/\text{day}$

$DT = \frac{V}{Q} = \frac{4 \times 2 \times 1.5}{18} = 0.67 \text{ days}$

(a) Rate of sludge production

= 40 lit/person/year

Cleaning period = 2 yrs

Volume of sludge produced = ?

$Q_{\text{sludge}} = 120 \times 40 = 4.8 \text{ m}^3/\text{year}$

Volume of sludge = 4.8 × 2 = 9.6 m³

(b) Percolation capacity of pit

= 1500 lit/m³/day

Volume of soak pit = ?

Volume of soak

pit = $\frac{Q}{\text{Percolation capacity}}$

$$= \frac{120 \times 150}{1500} = 12 \text{ m}^3$$



06. Ans: (d)

Sol: $V = 7 \text{ m}^3$

No. of users = 5

R.S.P = 70 lit/capita/year

$$\text{Volume of sludge zone} = \frac{V}{2} = \frac{7}{2}$$

Cleaning interval = cleaning period

Volume of sludge zone = RSP × no. of user × C.P

$$\frac{7}{2} = 70 \times 10^{-3} \times 5 \times \text{C.P}$$

$$\begin{aligned} \text{C.P} &= \frac{7/2}{70 \times 10^{-3} \times 5} \\ &= 10 \text{ years} \end{aligned}$$

Chapter-9
Oxidation Ponds

01. Ans: L = 282.84m, B = 70.71m,

DT = 50 days

Sol: Q = population × per capita supply × Factor

$$= 10,000 \times 100 \times 0.8$$

$$= \frac{1000000 \times 0.8}{10^6} = 0.80 \text{MLD}$$

y = 40 g/day

D.T = ?

80% of BOD removal

BOD loading rate = 200 kg BOD/hect/d

Total BOD = Q × y_i

= population × per capita BOD

$$= 0.8 \times y_i = 10,000 \times 100 \times 40 \times 10^{-3}$$

$$y_i = 500 \text{ mg/lit}$$

$$\begin{aligned} \text{Surface area of pond} &= \frac{Q \times y_i}{\text{BOD loading rate}} \\ &= \frac{0.8 \times 500}{200} = 2 \text{ ha} \end{aligned}$$

$$\text{Surface area} = 2 \text{ ha} = 2 \times 10^4 \text{ m}^2$$

$$L = 4B$$

$$L \times B = 2 \times 10^4$$

$$4B \times B = 2 \times 10^4$$

$$B = \sqrt{\frac{2 \times 10^4}{4}} = 70.71 \text{ m}$$

$$L = 4 \times 70.71 = 282.84 \text{ m}$$

$$\text{D.T} = \frac{\text{Volume of pond}}{Q} = \frac{L \times B \times H}{Q}$$

$$= \frac{282.84 \times 70.71 \times 2}{0.8 \times 10^6 \times 10^{-3}} = 50 \text{ days}$$

$$\eta = 80 = \frac{y_i - y_e}{y_i} \times 100$$

$$80 = \frac{500 - y_e}{500} \times 100$$

$$y_e = 500 - 400 \Rightarrow 100 \text{ mg/l}$$

02. Ans: L = 244.9 m, B = 61.23m, H = 1m

Sol: P = 10,000; sewage flow = 150 lpcd

$$Q = \frac{10000 \times 150}{10^6} = 1.5 \text{MLD}$$

y_i = 300 mg/l, y_e = 30 mg/l,

OLR = 300 kg/ha/d

$$k_D = 0.23 \text{d}^{-1}, L:B = 4:1$$



$$\therefore \text{D.T.} = \frac{1}{0.23} \times \ln \frac{300}{30} = 10 \text{ days}$$

$$\therefore \text{Surface area} = \frac{Qy_i}{\text{OLR}} = \frac{1.5 \times 300}{300} = 1.5 \text{ ha}$$

$$L \times B = 1.5 \times 10^4 \text{ m}^2$$

$$4B \times B = 1.5 \times 10^4$$

$$B = 61.23 \text{ m}$$

$$\therefore L = 4 \times 61.23 = 244.92 \text{ m}$$

$$\text{Vol of oxidation pond} = Q \times \text{DT}$$

$$= \frac{1.5 \times 10^6}{10^3} \times 10 = 15000 \text{ m}^3$$

$$\text{Depth of pond, } H = \frac{\text{Vol. of pond}}{\text{Surface area of pond}}$$

$$= \frac{15000}{15000} = 1 \text{ m}$$

05. Ans: (c)

$$\text{Sol: } Q = 10000 \times 200 = 2 \text{ MLD, } y = 300 \text{ mg/l}$$

$$\text{Organic loading rate} = 310 \text{ kg/day/ha}$$

$$\text{Surface area of pond} = \frac{Q y_i}{\text{BOD loading rate}}$$

$$= \frac{2 \times 300}{310} = 1.93 \simeq 2 \text{ ha}$$

Chapter- 10 Disposal of Sewage Effluents

01. Refer to ESE Volume-II (objective) Book

03. Ans: (c)

$$\text{Sol: Waste water } (\text{DO})_w = 2 \text{ mg/l}$$

$$Q_w = 1.10 \text{ m}^3/\text{sec}$$

$$(\text{DO})_R = 8.3 \text{ mg/l}$$

$$Q_R = 8.70 \text{ m}^3/\text{sec}$$

$$(\text{DO})_{\text{mix}} = \frac{(\text{DO})_w \cdot Q_w + (\text{DO})_R \cdot Q_R}{Q_w + Q_R}$$

$$(\text{DO})_{\text{mix}} = \frac{2 \times 1.10 + 8.3 \times 8.70}{1.10 + 8.70}$$

$$(\text{DO})_{\text{mix}} = 7.6 \text{ mg/l}$$

04. Ans: 13.85 mg/l, 20.27 mg/l, 5.85 mg/l

$$\text{Sol: } Q_w = 12000 \text{ m}^3/\text{d, temp} = 20^\circ\text{C,}$$

$$y_w = 50 \text{ mg/l}$$

$$(\text{DO})_w = \text{concentration} = 2 \text{ mg/l}$$

$$Q_R = 40,000 \text{ m}^3/\text{d, } y_R = 3 \text{ mg/l,}$$

$$(\text{DO})_R = 7 \text{ mg/l, temp} = 20^\circ\text{C}$$

$$K = 0.23 \text{ (to the base in decay curve)}$$

$$y_{\text{mix}} = \frac{Q_R y_R + Q_w y_w}{Q_R + Q_w}$$



$$= \frac{12000 \times 50 + 40,000 \times 3}{12,000 + 40,000} = 13.84 \text{ mg/lit}$$

$$(\text{DO})_{\text{mix}} = \frac{Q_R (\text{DO})_R + Q_w (\text{DO})_w}{Q_R + Q_w}$$

$$= \frac{12,000 \times 2 + 40,000 \times 7}{12,000 + 40,000}$$

$$= 5.85 \text{ mg/l}$$

$$y_{\text{mix}} = L_o(1 - e^{-k \times t})$$

$$13.85 = L_o(1 - e^{-0.23 \times 5}) = \frac{13.85}{(1 - e^{-0.23 \times 5})}$$

$$L_o = 20.27 \text{ mg/l}$$

06. Ans: 100 ha

Sol: $Q = 8 \text{ MLD}$,

Land capable of consuming

$$= 80000 \text{ lit/ha/day}$$

$$\text{Area of land} = \frac{Q}{\text{consuming capacity of soil}}$$

$$= \frac{8 \times 10^6}{80000}$$

$$= 100 \text{ ha}$$

07. Ans: 45000 lit/ha/day

Sol: $A = 140 \text{ ha}$, $Q = 4.5 \text{ MLD}$

$$\text{Area of land} = \frac{Q}{\text{consuming capacity of soil}}$$

$$140 = \frac{4.5}{\text{c.c.of soil}}$$

$$\text{C.C. of soil} \times 140 = 4.5$$

Let area of land required of sewage application = x . ha

Extra land provided for rest and rotation

$$= \frac{40}{100} x = 0.4 x$$

$$\text{Total land required} = x + 0.4x$$

$$1.4x = 140$$

$$x = 100$$

$$\text{Consuming capacity of soil} = \frac{Q}{\text{area of land}}$$

$$= \frac{4.5 \times 10^6}{100}$$

$$= 45000 \text{ lit/ha/day}$$

08. Ans: (b)

Sol: $Q_w = 8640 \text{ m}^3/\text{d}$, temp = 25°C ,

$$Q_w = \frac{8640}{24 \times 60 \times 60} = 0.1 \text{ m}^3/\text{s}$$

$$Q_R = 1.2 \text{ m}^3/\text{s}$$
, temp = 15°C

$$Q_R = 1.2 \times 24 \times 60 \times 60 = 103680 \text{ m}^3/\text{d}$$

$$t_{\text{mix}} = \frac{Q_R t_R + Q_w t_w}{Q_R + Q_w}$$

$$= \frac{1.2 \times 15 + 0.1 \times 25}{1.2 + 0.1} = 15.76^\circ\text{C}$$



09. Ans: (c)

Sol:

River	Waste water stream
$Q_R = 12 \text{ m}^3/\text{sec}$	$Q_w = 2 \text{ m}^3/\text{sec}$
$(L_0)_R = 5 \text{ mg/l}$	$(L_0)_w = 90 \text{ mg/l}$

$$(L_0)_{\text{mix}} = \frac{Q_R (L_0)_R + Q_w (L_0)_w}{Q_R + Q_w}$$

$$= \frac{12 \times 5 + 2 \times 90}{12 + 2} = 17.142 \text{ mg/l}$$

$$Q_{\text{mix}} = Q_R + Q_w = 12 + 2 = 14 \text{ m}^3/\text{sec}$$

$$\text{Velocity} = \frac{Q_{\text{min}}}{c/s \text{ area}} = \frac{14}{50} = 0.28 \text{ m/sec}$$

Time taken by the river to travel 10km

$$= \frac{10 \times 1000}{0.28} \times \frac{1}{24 \times 60 \times 60}$$

$$T = 0.413 \text{ days}$$

Ultimate BOD at 10 km $d/s = L_t = L_0 e^{-kt}$

$$k = 0.25 \text{ /day}$$

$$L_{0.413} = 17.142 e^{-0.25 \times 0.413} = 15.459 \text{ mg/lit}$$

$$\approx 15.46 \text{ mg/l}$$

10. Refer to ESE – Volume II(Objective)
Book

11. Refer to ESE – Volume II(Objective)
Book

12. Refer to ESE – Volume II(Objective)
Book

13. Refer to ESE – Volume II(Objective)
Book

Chapter- 11
Solid Waste Management

01. Ans: 14740 kJ/kg, 18658.2 kJ/kg,
19918.9 kJ/kg

Sol:

(i) Total energy content as discarded

$$= \sum \frac{P_i E_i}{100}$$

$$= \frac{15 \times 4650 + 45 \times 16750 + 10 \times 16300 + 10 \times 32600 + 10 \times 6500 + 5 \times 18600 + 5 \times 700}{100}$$

$$= 14740 \text{ kJ/kg}$$

(ii) Energy on dry basis = Energy as discarded

$$\times \frac{100}{100 - \%m.c}$$

$$= 14740 \times \frac{100}{100 - 21}$$

$$= 18658.22 \text{ kJ/kg}$$



(iii) Energy content on an ash – free dry basis

$$= \frac{100}{100 - \%m.c - \%ash}$$

$$= \frac{100}{100 - 21 - 5} \times 14740$$

$$= 19918.9 \text{ kJ/kg}$$

02. Ans: (b)

Sol:

$$\frac{100}{\rho_{Msw}} = \frac{\%F.W}{\rho_{Fw}} + \frac{\%DA}{\rho_{DA}} + \frac{\%pla}{\rho_p} + \frac{\%w \& y}{\rho_{w\&y}}$$

$$= \frac{50}{300} + \frac{30}{500} + \frac{10}{65} + \frac{10}{125}$$

$$= \frac{100}{\rho_{Msw}} = 0.46 \Rightarrow \frac{100}{0.46}$$

$$\rho_{Msw} = 217.1 \text{ kg/m}^3$$

04. Ans: (d)

Sol: 50 g of CO₂, 25 g = CH₄, 1 million people, rate of 500 ton/day

120 parts of MSW release 50 parts of CO₂ and 25 parts CH₄ 1 part of MSW release

$$\frac{75}{120} = 0.625 \text{ parts of green house}$$

500 t of MSW release = 0.625 × 500

Total green house = 321.5 of green house

Per capita green house gas contribution

$$= \frac{\text{Green house gas}}{\text{population of community}}$$

$$= \frac{321.5}{10,00,000} \times 1000 \times 1000$$

$$= 321.5 \text{ mg/l}$$

08. Ans: (c)

Sol: Solid waste is broadly classified into

- (i) Municipal
- (ii) Industrial
- (iii) Hazardous waste

09. Ans: (d)

Sol: The organic content in

$$\text{solid waste} = \text{Night soil} + \text{garbage}$$

$$= 35t + 40t = 75t$$

10. Ans: (b)

Sol: Except human excrete all forms of solid waste is treated as refuse

11. Ans: (a)

Sol: Solid waste sample composed more of organic matter. Therefore among the given options food waste is organic waste.

12. Ans: 1.46 ha

Sol: Population = 65000

Rate of solid waste = 2 kg/capita/day

Solid waste generated = 65000 × 2

$$= 130000 \text{ kg/day}$$

Solid waste generator per annum

$$= 130000 \times 365$$

$$= 47450000 \text{ kg/Annum}$$

$$\text{Volume} = \frac{\text{mass}}{\text{density}}$$

$$V = \frac{47450000}{650}$$



$$V = 73000 \text{ m}^3$$

$$\text{Area} = \frac{\text{Volume}}{\text{depth}} = \frac{73000}{5}$$

$$A = 14600 \text{ m}^2 \\ = 1.46 \text{ ha}$$

13. Ans: (a)

$$\text{Sol: } \frac{100}{\rho_{\text{sludge}}} = \frac{c_1}{\rho_1} + \frac{c_2}{\rho_2} \Rightarrow \rho_{\text{sludge}} = \frac{100}{\frac{c_1}{\rho_1} + \frac{c_2}{\rho_2}}$$

14. Ans: 13.6875

$$\text{Sol: Solid waste generated} \\ = 2 \times 10^5 \times 25 \times 365 \times 2 \\ = 3.65 \times 10^9 \text{ kg}$$

Volume of un-compacted

$$S_w = \frac{3.65 \times 10^9}{100} = 36.5 \times 10^6 \text{ m}^3$$

$$\text{Volume of compacted solid waste} = \frac{36.5 \times 10^6}{4} \\ = 9.125 \times 10^6 \text{ m}^3$$

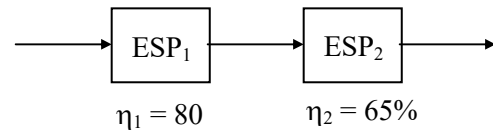
$$\frac{\text{Compacted fill}}{\text{Compacted solid waste}} = 1.5$$

$$\text{Volume of land fill (compacted fill)} \\ = 9.125 \times 10^6 \times 1.5 \\ = 13.6875 \times 10^6 \text{ million m}^3$$

Chapter- 12
Air Pollution and Control

05. Ans: (b)

Sol:



Let 'x' be concentration of particles in blue gas

$$\text{Particles removed by ESP}_1 \\ = 80\% (x) = 0.8x$$

$$\text{Particles remain in blue gas after ESP}_1 \\ = 0.2x$$

$$\text{Particles removed by ESP}_2 \\ = 65\% (0.2x) = 0.13x$$

$$\text{Particles remained in blue gas after ESP}_2 \\ = 0.07x$$

$$\text{Overall removed} \\ = \frac{x - 0.07x}{x} \times 100 = 93\%$$

06. Ans: (d)

$$\text{Sol: } \text{CHCl}_3 = 12 + 1 + 3 \times 35.5 \\ = 119.5 \text{ gm molecular.}$$

$$\text{Concentration} = 0.4 \mu\text{g} / \text{m}^3 @ 273^0 \text{ k}$$

$$T_1 = 273^0 \text{ k} \quad T_2 = 293^0 \text{ k}$$

$$P_1 = 1 \quad P_2 = 1$$

$$V_1 = 22.4 \text{ lit/ mol} \quad V_2 = ?$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$



$$\frac{22.4}{273} = \frac{V_2}{293} \Rightarrow V_2 = 24.04 \text{ lit / mol}$$

$$\mu\text{g / m}^3 = \frac{\text{PPM} \times \text{gm.mole.} \times 10^3}{\text{lit / mol}}$$

$$0.4 = \frac{\text{PPM} \times 119.5 \times 10^3}{24.04 \times 10^{-3}}$$

$$\text{PPM} = 8.047 \times 10^{-5} \times 10^3$$

$$[\because 1 \text{ billion} = 10^9] = 0.08$$

Parts per billion

$$= 8.047 \times 10^{-5} \times 10^3 = 0.08$$

09. Ans: (a)

Sol: Dry air cools at 9.8° per km
 $\approx 10^\circ$ km

For $\frac{1}{2}$ km $\rightarrow 5^\circ$ fall

Final temperature at 500 m elevation

$$= 40^\circ - 5^\circ = 35^\circ\text{c}$$

10. Ans: (c)

Sol: Volume of air sampled

= avg. rate of sampling \times duration of sampling

$$= \frac{1.5 + 1.4}{2} \times (24 \times 60) = 2088 \text{ m}^3$$

$$\text{TSP} = \frac{\text{final weight of filterpaper} - \text{Initial weight of filterpaper}}{\text{Volume of air sampled}}$$

$$= \frac{10.283 - 9.787}{2088} = 2.375 \times 10^{-4} \text{ gm / m}^3$$

$$= 2.375 \times 10^{-4} \times 10^6 = 237.547 \mu\text{g / m}^3$$

16. Ans: (c)

Sol: 20000 km, No. = 50,000

rate = 2 gm/km/vehicle

$$= 2 \times 50,000 \times 20000 \times \frac{1}{10^6} = 2000 \text{ t}$$

21. Ans: (a)

$$\text{Sol: Lapse rate} = \frac{dt}{dz} = \frac{T_2 - T_1}{Z_2 - Z_1}$$

$$= \frac{15.70 - 21.25}{444.4}$$

$$\text{ALR } 1 \text{ m} = -0.0126^\circ/2\text{m}$$

$$\text{Per } 100 \text{ m} = 0.0126 \times 106$$

$$\text{CLR} = 1.261^\circ/100\text{m}$$

CLR > ALR \rightarrow Super adiabatic

23. Ans: 0.011268

$$\text{Sol: } \frac{P}{RT} = 41.6 \text{ mol / m}^3$$

$$\frac{RT}{P} \times 10^3 = \text{constant} = 24.038$$

$$1 \mu\text{g / m}^3 = \frac{24.038}{M \times 10^3} \text{ ppm}$$

$$30 \mu\text{g / m}^3 \text{ of SO}_2 = \frac{24.038}{64 \times 10^3} \times 30$$

$$= 0.011268 \text{ ppm}$$



24. Ans: (b)

Sol: $v = \frac{2}{60} \text{ m/sec}$

Total surface area of bags required = $\frac{Q}{v}$

$$\frac{10}{2/60} = 300 \text{ m}^2$$

Surface area of each bag = πdH

$$= \pi \times 0.45 \times 7.5$$

$$\begin{aligned} \text{Number of bags required} &= \frac{300}{\pi \times 0.45 \times 7.5} \\ &= 28.29 \approx 29 \end{aligned}$$

25. Ans: 8012.38

Sol: η of ESP is given by

$$\eta = 1 - e^{-\frac{AW}{Q}}$$

when $\eta = 96\%$ $A = 5600 \text{ m}^2$

$\eta = 97\%$ $A = 6100 \text{ m}^2$

$\eta = 99\%$ $A = ?$

$$0.96 = 1 - e^{-\frac{5600 \times W}{185}} \Rightarrow W = 0.1063 \text{ m/sec}$$

$$0.99 = 1 - e^{-\frac{A \times 0.1063}{185}} \Rightarrow A = 8012.38 \text{ m}^2$$

plate area of collector $A = 8012.38 \text{ m}^2$

26. Ans: 592.88

Sol: % sulphur in coal = 2

Rate of coal consumption = 30 kg/min

% sulphur in ash = 6

$$\text{SO}_2 \text{ emission} = \left(\frac{\text{t}}{\text{year}} \right) = ?$$

Total sulphur produced = Rate of Coal consumption \times % sulphur in Coal

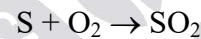
$$30 \times \frac{2}{100} \text{ kg/min} \times \frac{365 \times 24 \times 60}{1000} \times \text{t/year}$$

(Convert in to tonn/year)

SO₂ emission of gas

$$= 30 \times \frac{2}{100} \times \frac{365 \times 24 \times 60}{1000} \left(\frac{100 - 6}{100} \right)$$

$$= 296.45 \text{ /year}$$



$$\text{S} = 32$$

$$\text{SO}_2 = 64$$

$$32 \text{ Parts of sulphur} = 64 \text{ parts of SO}_2$$

$$1 \text{ Part of SO}_2 = \frac{64}{32} \text{ parts of SO}_2$$

$$296.4 \text{ t/year of sulphur produce}$$

$$= \frac{64}{32} \times 296.4 \text{ t/year of SO}_2$$

$$\text{SO}_2 \text{ emission} = \frac{64}{32} \times 296.4$$

$$= 529.8$$

27. Refer to ESE – Volume II(Objective) Book

28. Refer to ESE – Volume II(Objective) Book

29. Refer to ESE – Volume II(Objective) Book



30. Refer to ESE – Volume II(Objective)
Book

31. Refer to ESE – Volume II(Objective)
Book

Chapter- 13
Noise Pollution

01. Ans: (b)

Sol: $L_1 = 60 \text{ dB} = 20 \log_{10} \frac{P_1}{P_0} = 20 \log_{10} \frac{P_1}{20}$

$P_1 = P_2$

$P_{\text{rms}} = \sqrt{(20000)^2 + (20000)^2} = 28284.27 \text{ dB}$

Total SPL = $20 \log_{10} \frac{P_{\text{rms}}}{P_0}$
 $= 20 \log_{10} \frac{28284.27}{20}$
 $= 63 \text{ dB (or)}$

(or) $60 + 3 = 63 \text{ dB}$

02. Ans: (b)

Sol: $L_1 = 80 \text{ dB}, L_2 = 60 \text{ dB}$
 $80 + 0 = 80 \text{ dB}$

03. Ans: (a)

Sol: $I = 20 \log_{10} \times \frac{1}{4} \sum \left(10^{\frac{20}{20}} + 10^{\frac{56}{20}} + 10^{\frac{66}{20}} + 10^{\frac{42}{20}} \right)$
 $= 56.8 \text{ dB}$

04. 87.3 dB

$$l_{\text{eq}} = 10 \log_{10} \sum \left(10^{\frac{t_i}{10}} \times T_i \right)$$

$$T_i = \frac{t_i}{T}$$

Total time = $10 + 80 + 5 = 95$

$$l_{\text{eq}} = 10 \log_{10} \left(10^{\frac{80}{10}} \times \frac{10}{95} + 10^{\frac{60}{10}} \times \frac{80}{95} + 10^{\frac{100}{10}} \times \frac{5}{95} \right)$$

$$= 87.3 \text{ dB}$$

05. Ans: (c)

Sol: $P = 2000 \mu \text{ bar}$

Particular = $10^5 \text{ N/m}^2 \text{ cPa}$

$1 \mu \text{ bar } 10^{-6} \times 10^5 \text{ N/m}^2 = 0.1 \text{ Pa}$

$\Rightarrow 10^{-6} \times 10^5 \times 10^6 = 10^5 \mu \text{ Pa}$

$1 \mu \text{ bar} = 10^6 \text{ MPa}$

$l = 20 \log_{10} \frac{2000 \times 10^5}{20}$
 $= 140 \text{ dB}$

08. Ans: (a)

Sol:

$$20 \log_{10} \frac{P}{P_{\text{ref}}} = L$$

$P = 0.0002 \mu$

$L = 20 \log_{10} \frac{0.0002 \times 10^5}{20} = 0 \text{ dB}$



09. Ans: (c)

Sol:

$$50 \text{ dB} + 50 \text{ dB}$$

$$50 + 3 = 53 \text{ dB}$$

10. Ans: 74 dB

Sol: $L_1 = 80 \text{ dB}$, $r_1 = 20 \text{ m}$

$L_2 = ?$, $r_2 = 40 \text{ m}$

$$L_2 = L_1 - 20 \log_{10} \left(\frac{r_2}{r_1} \right)$$

$$L_2 = 80 - 20 \log_{10} \left(\frac{40}{20} \right)$$

$$L_2 = 73.98 \text{ dB} \simeq 74 \text{ dB}$$

