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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

7000 6000 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	$\frac{1.68-1.4}{1.4}\times 100 = 20$

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

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

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

$$P_0 = 1.68\,\text{lakh}$$

$$P_1 = P_0\left(1+\frac{\bar{r}}{100}\right)^1$$

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

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

03. Ans: 1.37, 1.97 billion

Sol: K = 1.6% per year

P_{2000} = 1 billion

P_{2020} = ?

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

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

P_{2020} = 1.37 billion

04. **Ans: 68000**

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

$\bar{y} = 500$ per decade

P_{2020} = ?

P_{1990} = 50000 (given)

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

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

$P_{2020} = 50000 + 3 \times 5000 + \frac{3\times4}{2}\times500$

$P_{2020} = 68000$

05. Ans: 743900

Sol:

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

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

$\bar{x} = 111300$

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

$\bar{y} = -57966.67$

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

$P_{2000} = ?$

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

$$P_{2000} = 695200 + 2\times111300 + \frac{2(2+1)}{2}(-57966.67)$$

$P_{2000} = 743900$

Per capita water supply = 200 *l*pcd

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

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

$= 148.7$ MLD $= 149$ 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		$\frac{158500}{400000}\times100 = 39.6\%$
		217500 (dP_2)	
3	776000		$\frac{217500}{558500}\times100 = 38.94\%$
		322500 (dP_3)	
4	1098500		$\frac{322500}{776000}\times100 = 41.5\%$
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,

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

$4200 m^3/d$ required for 28,000 persons

$6000 m^3/d$ sufficient for ------- persons

$$= \frac{28000\times6000}{4200} = 40,000$$

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

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

$n = 1.5$ decades $= 15$ 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

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

$r_0 = 11.5$

$$P_n = P_o\left[1 + \frac{r_o - \overline{D}}{100}\right]\left[1 + \frac{r_o - 2\overline{D}}{100}\right] ..... \left[1 + \frac{r_o - n\overline{D}}{100}\right]$$

P_o = latest known population

P_n = prospective population after n year

r_o = latest per decade percentage increase in population

$\overline{D}$ = average decrease in percentage increase

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

$$\overline{D} = 1.635$$

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

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

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

= 79500 (1.09865) (1.0823) (1.06595)

= 100765.29

$\simeq$ 100765

$\therefore$ 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.

$\therefore$ [Both statements are correct R is the correct reason for "A"].

02. Ans: (b)

Sol: Total area of slots required =

$$\frac{Q}{V} = \frac{8\times10^{-3}}{2\times10^{-2}} = \frac{m^3/s}{m^2/s} = 0.4m^2$$

Area of each slot = $(2\times10^{-3}) \times (0.2\times10^{-3})$

= 4×10^{-6} m^2

Number of slots required =

$$\frac{\text{Total area of slots required}}{\text{Area of each slot}}$$

$= \frac{0.4}{4\times10^{-6}}$ = 1,00, 000

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

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

= 1000 cm = 1 m

03. Ans: (b)

Chapter- 3
Quality of Water

01. Ans: (d)

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

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

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

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

TH = 567 mg/l *as* $CaCO_3$

04. Ans: (c)

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

FTN = 8

05. Ans: (d)

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

11. Ans: (a)

Sol: TH = 200 mg/l as $CaCO_3$

TA = 250 mg/l as $CaCO_3$

TH < TA

CH = TH = 200 mg/l

12. Ans: (d)

Sol: NCH = TH– CH

= 200–200 = 0

14. Ans: (d)

Sol: $(pH)_I = 7.2, \quad (H^+)_I = 10^{-7.2}$ mol/lit

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

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

$$H^+ = \frac{10^{-7.2} + 10^{-8.4}}{2} = 3.3\times10^{-8}\ \text{mol/lit}$$

$$pH = \log_{10}\frac{1}{H^+} = \log_{10}\frac{1}{3.3\times10^{-8}}$$

pH = 7.47

15. Ans: (c)

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

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

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

16. Ans: (a)

Sol: Sample A, V_A = 300 ml

$(pH)_A = 7$

$(H^+)_A = 10^{-7}$ mol/lit

Sample B, V_B = 700 ml

$(pH)_B = 5$

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

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

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

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

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

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

17. **Ans: (d)**

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

$HCO_3^- = 61$ mg/*l*

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

$$TA = 90 \times \frac{50}{30} + 61 \times \frac{50}{51}$$

TA = 200 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 × 10 = 330 no/100 m*l*

19. **Ans: (a)**

Sol: pH = 9

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

$OH^- = 10^{-5}$ 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 mg/*l* as $CaCO_3$

TH= 350 mg/*l* as $CaCO_3$

TH > TA

CH = TA = 250 mg/*l*

NCH = TH – CH = 350 –250

NCH = 100 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 ≃ 179 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 mg/lit as $CaCO_3$

30. Ans: (c)

Sol: Alkalinity in mg/lit $CaCO_3$

$$= HCO_3^- \text{ in mg/lit} \times \frac{50}{61} + CO_3^{2-} \text{ in mg/lit} \times \frac{50}{30}$$

$$= (30 \times 61) \times \frac{50}{61} + (5 \times 30) \times \frac{50}{30}$$

= 1750 mg/lit as $CaCO_3$

Common data for Question Nos. 31. & 32

31. Ans: (c)

Sol: $TH = 100 \times \frac{50}{20} + 6 \times \frac{50}{12}$

= 275 mg/lit as $CaCo_3$

32. Ans: (a)

Sol: $\text{Alkalinity} = 250 \times \frac{50}{61}$

$= 204.9 \approx 205 \text{mg/lit } as\ CaCO_3$

33. Ans: (d)

Sol: Tomoto juice pH = 4.1

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

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

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

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

34. Ans: (d)

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

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

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

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

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

pH = 5.4

36. Ans: (d)

Sol:

From table 10–1–0.10 (MPN) against

2–1–0 + ve group

MPN = 7

For 1–0.1 –0.01 dilution against

2–1–0, +ve group

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

MPN = 7 ×10 = 70

37. Ans: (b)

Sol: Mol. Wt of CO_3 = 12 + 3×16 = 60

Mol. Wt. of Ca = 40

60 parts of CO_3 required = 40 parts of Ca

1 part of CO_3 require $= \frac{40}{60}$ part of Ca

90 mg/l part of CO_3 require $= \frac{40}{60} \times 90$ mg/l of Ca

= 60 mg/l of Ca

38. Ans: (c)

Sol: pH = 9.25

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

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

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

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

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

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

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

OH^- = 0.302 mg/l as $CaCO_3$

39. Ans: (d)

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

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

TON = 16

40. Ans: (b)

Sol: OH^- = 17 mg/l

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

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

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

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

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

pH = 11

41. Ans: (b)

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

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

HCO_3^- = 3.5 m. eq/lit

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

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

= 4×50+1×50 = 250 mg/l as $CaCO_3$

TA = $CO_3 \times 50 + HCO_3 \times 50$

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

= 0+3.5×50 = 175 mg/l as $CaCO_3$

TH > TA

$\therefore$ CH = TA = 175 mg/l as $CaCO_3$

NCH = TH – CH = 250 – 175

= 75 mg/l as $CaCO_3$

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

Sol: W_1 = 98.42 gm

W_2 = 98.484 gm

W_3 = 98.462 gm

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

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

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

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

Volatile solid

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

= 220 mg/l

Fixed solids = $\frac{W_3 - W_1}{V}$

$= \frac{98.462 - 98.42}{100} \times 10^6$

$= 420$ mg/l

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

Surface over flow rate $V_0 = \frac{2\times10^6}{6\times15\times24}$

= 926 lit/hr/m^2

02. Ans: (d)

Sol: Detention time is

Volume of setting tank = Q × D.T

$DT = \frac{6\times15\times3}{\frac{2\times10^6}{24\times10^3}} = \frac{270}{83.33} = 3.24$ hrs

03. Ans: (a)

Sol: η = 70%, V_0 = 926 lit/hr/m^2

$\eta = \frac{V_S}{V_0}\times100$

Total solids removed

= Q × concentration of solids (MLD × mg/lit)

= 2 × 70

= 140 kg/day

Total amount of dry solids removed

= Total amount of solids in water × η

$= 140 \times \frac{70}{100} = 98$ kg/day

Common data for Qs. 04 & 05

04. Ans: (c)

Sol: Q = 1.8 MLD

D.T = 4 hours

V = ?

$= \frac{1.8\times10^6}{10^3\times24} = 75\ m^3/hr$

Volume of tank = Q × DT

= 75 × 4 = 300 m^3

05. Ans: (b)

Sol: SOR = 500 lit/hr/m^2, L:B = 4:1, L =?

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

Surface area = $\frac{Q}{SOR} = \frac{1.8\times10^6}{24\times500}$

L × B = 150 m^2

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

$L^2 = 150\times4 \Rightarrow L = 24.49$ m

06. Ans: 0.0112 m/sec

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

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

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

$$= \frac{9.81(2.65-1)\times(0.025\times10^{-3})^2}{18\times\frac{0.01}{(100)^2}}$$

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

$$\frac{60}{V_H} = \frac{3}{5.62\times10^{-4}}$$

$\Rightarrow V_H = 0.0112$ m/sec

07. Ans: (c)

Sol: Q = 100000 m^3/day

Settling velocity = 20 m /day

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

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

08. Ans: (a)

Sol: d = 0.025 mm, s = 2.65, ν=0.01 cm^2/sec

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

$$= \frac{9.81(2.65-1)\times(0.025\times10^{-3})^2}{18\times0.01\times10^{-4}}$$

= 0.056 cm/sec

09. Ans: 27.08, 100%

Sol: V_0 = 12,000 lit/hr/m^2, d = 0.03 mm

= 12 m^3/hr/m^2

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

$$= \frac{9.81(2.65-1)(0.03\times10^{-3})^2}{18\times\frac{0.897}{(1000)^2}}$$

$= V_S = 0.922$ mm/sec

$V_S = 9.02\times10^{-4}$ m/sec

$$\eta = \frac{V_S}{V_0}\times100$$

$V_0 = 12\ m^3/hr/m^2 = 3.33\times10^{-3}$ m/sec

$$= \frac{9.02\times10^{-4}}{3.33\times10^{-3}}\times100$$

= 27.08%

b) d = 12 mm > 1 mm

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

$$= 18\sqrt{9.81(2.65-1)\times(12\times10^{-3})}$$

$$\eta = \frac{V_S}{V_0}\times100 = \frac{0.79\times100}{3.33\times10^{-3}}\times100 = 100\%$$

Common Data for Qs. 10 & 11

10. Ans: (a)

Sol: d = 26 m with H = 2.10 m

Q = 13000 m^3/day, D.T = ?

$$DT = \frac{2.10\times\left(\frac{\pi}{4}\times26^2\right)}{\frac{13000}{24}} = 2.05\text{ hrs}$$

11. Ans: (d)

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

$$= \frac{13000}{\pi\times26}$$

= 159 m^3/day/m

12. Ans: 44.5, 14.83 & 0.47

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

$G = 2.3$, $Q = 100$ MLD, $H = 3m$

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

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

$$= \frac{9.81(2.3-1)\times(0.05\times10^{-3})^2}{18\times1.01\times10^{-6}}$$

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

For 100% removal

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

$$\text{Surface area} = \frac{Q}{V_0} = \frac{1.157}{1.753\times10^{-3}}$$

$L : 3B = 660.011$

$L \times B$

$3B \times B = 660.011$

$3B^2 = 660.011$

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

$L = 3 \times B = 3 \times 14.83 = 44.49$ m

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

$$\frac{44.49\times14.83\times3}{\frac{100\times10^6}{24\times10^3}} = 0.47\ hr$$

13. Ans: 20 m^3/m^2/day

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

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

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

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

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

$$= \frac{100000}{100\times50}$$

$= 20\ m^3/m^2/day$

For 100% removal $V_S = V_0$

$= 20\ m^3/m^2/day$

14. Ans: (c)

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

$Q = 8000\ m^3/day$, $T = 20^0C$,

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

$d = 0.01$ mm, $G = 2.65$, $\eta = ?$

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

$$= \frac{8.8}{24\times60\times60}\ m/sec = 1.0185\times10^{-4}\ m/s$$

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

$$= \frac{9.81(2650-1000)\times(0.01\times10^{-3})^2}{18\times10^{-3}}$$

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

Proportion of particle removed 'η'

$$= \frac{V_S}{V_0}\times100$$

$$= \frac{8.99\times10^{-5}}{1.018\times10^{-4}}\times 100 = 88.31\%$$

Common data for Question Nos. 15 & 16

15. Ans: (a)

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

$T = 20^0C$, $\mu = 1.002 \times 10^{-3}\ \frac{N-s}{m^2}$ at 20^0C,

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

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

$$= \frac{4\times10^6\times10^{-3}}{20\times10}$$

$$= 20\ m^3/m^2/day$$

16. Ans: (b)

Sol: $\eta = 100\%$

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

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

$\rho_p = 2645.23\ kg/m^3$

$$\frac{20}{24\times60\times60} = \frac{9.81(2645.23-998.2)d^2}{18\times1.002\times10^{-3}}$$

d = 0.016 mm

17. Ans: (b)

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

$V_{S3} = 1.0$ mm/s

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

Particle	Percentage	V_S mm/sec	$\eta = \frac{V_S}{V_0}\times100$
1	10	0.1	$\eta_1 = \frac{0.1}{0.5}\times100 = 20$
2	60	0.2	$\eta_2 = \frac{0.2}{0.5}\times100 = 40$
3	30	1.0	$\eta_3 = \frac{1}{0.5}\times100 = 100$

$V_0 = 43.2\ m^3/m^2/day$

$$V_0 = \frac{43.2\times10^6}{10^3\times24\times60\times60} = 0.5\ mm/sec$$

Overal removal = ΣPini

$$= \frac{10}{100}\times20 + \frac{60}{100}\times40 + \frac{30}{100}\times100$$

= 56%

18. Ans: (b)

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

$\rho = 1000\ kg/m^3$

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

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

$\rho_w = 1000\ kg/m^3$

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

$$= \frac{9.81(2650-1000)d^2}{18\times0.001}$$

$$= \frac{30\times10^3}{24\times60\times60} = \frac{16186.5d^2}{0.018}$$

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

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

d = 0.02 mm

19. Ans: 3.124

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

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

$G = 2.65$

$\upsilon = 1.0105\times10^{-2}\text{ cm}^2/\text{sec}$

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

$$V_s = \frac{9.81\times(2.65-1)\times(0.06\times10^{-3})^2}{18\times1.0105\times10^{-6}}$$

$V_s = 3.20\times10^{-3}\text{ m/sec}$

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

$$A = \frac{0.01}{3.20\times10^{-3}} = 3.124\,m^2$$

20. Ans: 22.576

Sol: $\eta = \frac{V_s}{V_o}\times100$

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

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

$$\eta = \frac{V_s}{V_o}\times100$$

$$\Rightarrow 90 = \frac{V_s}{4.629\times10^{-4}}\times100$$

$V_s = 4.166\times10^{-4}\text{ m/sec}$

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

$$\Rightarrow 4.166\times10^{-4} = \frac{9.81[2.65-1]}{18\times1.1\times10^{-6}}d^2$$

$d = 22.576\times10^{-6}\text{ m}$

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

21. Ans: 112.66

Sol: Surface over flow rate

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

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

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

$$\Rightarrow 32.5\times8 = \frac{Q}{32.5}$$

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

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

$$= \frac{32.5\times8\times32.5}{75}$$

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

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	$\frac{1}{3} \times 100 = 133.33$	$300 \times \frac{33.33}{100} = 100\,\text{mg}/\ell$	200 Mg/*l*

26. Ans: (b)

Sol: $V = 2500\ m^3$

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

DT = ?

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

$$= \frac{24}{10}\text{hr}$$

27. Ans: (a)

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

$Q = 2400\ m^3$/day

V_s = ?

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

For 100%

$V_s = V_o = 24$ m/day

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

28. Ans: (b)

Sol:

Particle	Settling velocity $\frac{}{(m/hr)}$	Initial concentration (mg/ l)	n × C_{in} mg/l
1	1	100	$n_1 = \frac{1}{1}\times100 = 100$
2	0.5	100	$n_2 = \frac{0.5}{1}\times100 = 50$
3	0.1	100	$n_3 = \frac{0.1}{1}\times100 = 10$
4	0.05	100	$n_4 = \frac{0.05}{1}\times100 = 5$
			Total = 165 mg/ l

$= V_o = 1\ m^3/m^2/$ hour

$= V_o = 1$ m/hour

Concentration of particle removed = 165 mg/l

Chapter- 5
Coagulation

Common Data Question 01 & 02

01. **Ans: (c)**

Sol: Q = 10MLD = 10× 10^6 $l$it/day

Alum = 20 mg/$l$it

1 mg of Alum requires 0.45 mg of Alkaline as $CaCO_3$

$\therefore$ 20 mg/Lit of alum requires

= 20×0.45 = 9 mg of alkaline as $caco_3$ per Lt of water

$\therefore$ Total alkalinity matching filter

Alum = 9 mg/Lit = 10×10^6 Lit /day

= 90×10^6

Total alkanity requirement

(10^6 mg per day) = 90

02. **Ans: (d)**

Sol: Natural available alkalinity = 6 mg/ Lit

$\therefore$ Alkalinity to be added additionally

= 9 – 6 = 3 mg/Lit

$\therefore$ Alkaline to be added to the water

= 3 × 0.56 = 1.68 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

CO_2 gas = ?

Total alum requirement/day

= Q × alum dose

= 12 × 14 = 168 kg/day

$Al_2(SO_4)_3 = 18\ H_2O + Ca(HCO_3)_2$

$\rightarrow 3CaSO_4 + 2Al(OH)_3 + 6CO_2 + 18H_2O$

Molecular weight of alum = 666

Molecular weight of $6CO_2 = 6[C(O_2)]$

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

= 264

666 parts alum release = 264 parts of CO_2

1 part alum release = $\frac{264}{666}$ parts of CO_2

14 mg/l of alum release = $\frac{264}{666} \times 14$ mg/*l* of CO_2

= 5.54 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-?

$= FeSO_4 . 7H_2O$

Total quantity of ferrous sulphate req/day

= Q × dosage of ferrous sulphate

= 10 × 12= 120 kg/day

$FeSO_4\ 7H_2O + Ca(OH)_2$

$\rightarrow CaSO_4 + Fe(OH)_2 + 7H_2O$

$Ca(OH)_2 \rightarrow CaO + H_2O$

Molecular weight of $FeSO_4$.

$7H_2O = Fe + S + 4(O) + 7(2+H+O]$

Molecular weight of CaO = 56

278 parts of ferrous sulphate required

= 56 parts of CaO

1 part of ferrous sulphate required

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

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

= 2.014 mg/*l*

Total lime as CaO required/day

= Q × dose of CaO

= 12 × 2.014

= 24.168 kg/day

05. Ans: 37800 kg

Sol: Q = 35 m^3/min = 50.4 MLD

Dose of alum = 25 mg/*l*

Total alum required in kg/day

= Q (MLD) × dose of alum (mg/*l*)

= 50.4 ×25 = 1260 kg/day

Monthly alum requirement = 1260 × 30

= 37800 kg

06. Ans: (b)

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

$$600 = \sqrt{\frac{P}{2\times1\times10^{-3}}}$$

$P = (600)^2\times2\times1\times10^{-3} = 720$ Watts

07. Ans: (d)

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

$\rho_w = 1000\ kg/m^3$

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

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

$DT = 2$ min

Volume of mixing basin $= Q \times DT$

$$V = \frac{28800\times2}{24\times60} = 40\,m^3$$

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

$$900 = \sqrt{\frac{P}{40\times10^{-6}\times1000}}$$

$P = 32400$ watts

08. Ans:1613.92 Watts

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

D.T = 20 min, $\mu = 1.0087\times10^{-3}$ N-S/m^2

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

$\dfrac{L}{B} = 2$, $D = 0.40B$

$L = 2B$

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

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

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

$0.80B^3 = 1000$

$B = 10.77$ m, $L = 21.54$ m, $D = 4.3$ m

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

$$40 = \sqrt{\frac{P}{1000\times1.008\times10^3}}$$

$P = 1613.92$ Watts

10. Ans: (b)

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

$V_0 = 0.2$ mm/sec; $d = 3.5$ m

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

$$0.2\times10^{-3} = \frac{4.2}{60\times A}$$

$A = 350\ m^2$

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

ROF = 180 lit/hr/m^2

Q = Population × per capita demand

Q = 50,000 × 150

= 7500000 lit/day

Design discharge $Q_{density}$ = 1.8 × Q

= 1.8 × 7500000

= 135 × 10^5 lit/day

ROF = 180 lit/hr/m^2

Total area of slow sand filter = $\dfrac{Q_{density}}{ROF}$

$$= \frac{135\times10^5}{180\times24}\ \frac{\text{lit / hr}}{\text{lit / hr / m}^2} = 3125\ m^2$$

No. of filters in operations = 5

(1 act as stand by)

Area of each filter L × B

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

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

L : B = 2 : 1 ⇒ L = 2B

2B × B = 625 m^2

B^2 = 625/2

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

L = 35.35 m

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

Sol: Q = 24 MLD, ROF = 5 m^3/hr/m^2,

L.B = 2 : 1

$$Q = \frac{24\times10^6\times10^{-3}}{24} = 1000 m^3/hr$$

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

No. of filters = 1

Area of filter = 200 m^2

L: B = 200 2B × B = 200

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

B = 10 m

L = 2 × 10 = 20 m

Volume of water filter b/w back wash

= ROF × duration of filtration × area of each filter

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

= 23833.33m^3

Volume of water used in back wash ROB × DOB × area

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

% of filter water used in back wash

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

$$= \frac{1000}{23833.3}\times100 = 4.19\%$$

03. Ans: 9.48 m, 4.74 m, 0.225 m^3/sec

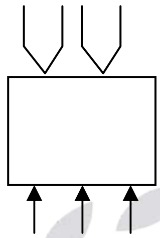
Sol: Q = 0.25 m^3/sec, No. of filters = 4,

ROF = 5m^3/m^2/hr

Back wash water, 10 l/m^2/sec,

L : B = 2 : 1

L = ?, B = ?



$$\text{Total area of RSF} = \frac{Q}{ROF} = \frac{0.25}{\frac{5}{60\times 60}}$$

$$= \frac{0.25\times 60\times 60}{6}$$

$$= 180\ m^2$$

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

$$L \times B = 45$$

$$2B \times B = 45$$

$$2B^2 = 45$$

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

$$L = 2 \times 4.74 = 9.48\ m$$

Back wash water flow rate ROB

= velocity (V_B) × Area of each filter

= 10 × 45 = 450 lit/sec

= 0.45 m^3/sec

There are two troughs

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

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

04. Ans: 0.27 m

Sol: V_s = 3m/hr

L = 0.6m $\qquad \phi = 0.8$

d = 0.5 mm $\qquad$ e = 0.4

S = 2.65 $\qquad \nu = 1\times 10^{-6} m^2/sec$

$$Re = \frac{(V_s.d)\phi}{\nu}$$

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

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

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

$$= 271.75$$

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

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

$$= 0.27\ m$$

05. Ans: 0.032 m/sec, 0.6258 m

Sol: d = 0.65 mm, S = 2.66, n = 0.42, z = 65 cm

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

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

$$= 0.29\ mm/sec$$

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

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

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

$n_e = 0.613$

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

Head loss during back wash h_b

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

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

$= 0.6258$ m

06. Ans: (a)

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

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

$Z_2 = ?$

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

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

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

$Z_2 = 0.10$ m

Common data for Question Nos. 07 & 08

07. Ans: (c)

Sol: ROF = 200 $m^3/m^2/d$,

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

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

$= 216\ mm^2$

08. Ans: (c)

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

Total no. of filters = 6

11. Ans: 144 m^3/day/m^2

Sol: Q = 1m^3/sec = 86400 m^3/day

no.of filters = 14

surface area of each filter = 50m^2

no. of filters in working condition

= 14 – 2=12

$$\text{Loading rate} = \frac{Q}{\text{surface area}} = \frac{86400}{12\times 50}$$

= 144 m^3/day/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**

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

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

DOB : 15 min

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

= ROB × DOB × (L × B) + ROF ×

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 × 150

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

Bleaching powder = 0.2 mg/l

Cl_2 = 0.2 ppm = 0.2 mg/l

$Ca(OCl)_2$ = 30% available Cl_2

Bleaching powder

$$= \frac{Cl_2 \text{ dose}}{\%\text{ of } Cl_2 \text{ bleaching powder}}$$

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

Total bleaching powder required/day

= 3 × 0.66

= 2 kg/day

02. Ans: (c)

Sol: Q = 20,000 m^3/day

Total Cl_2 used = 8 kg/day

Residual Cl_2 = 0.15 mg/l

Dose of Cl_2 = ?

Demand = ?

Total Cl_2 = Q × design of Cl_2

8 = 20,000 × dose of Cl_2 MLD

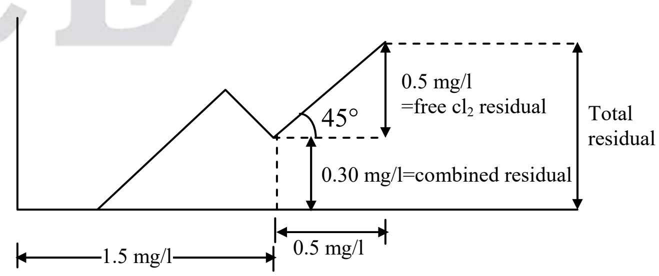
Dose of Cl_2 = $\frac{8}{20}$ = 0.4 mg/l

Cl_2 demand = Cl_2 dose – Residual Cl_2

= 0.4 – 0.15 = 0.25 mg/l

03. Ans: (b)

Sol:



Total residual = 0.3 + 0.5 = 0.80 mg/l

04. Ans: (b)

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

$$0.9=\frac{1}{1+\frac{2.7\times10^{-8}}{H^+}}$$

$H^+ = 2.7\times10^{-7}$ mol/lit

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

$pH \approx 6.568$

08. Ans: 3.2 min

Sol: Residual = 0.6 mg/l,

K = 3×10^{-2} per sec

t = ?

$$\%\text{ of kill}=\frac{N_o-N_t}{N_o}\times100$$

$99.7 = (1-e^{-kt})\times100$

$99.7=\left(1-e^{-3\times10^{-2}t}\right)\times100$

$99.7 = (0.029\times t)\times100$

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

09. Ans: 0.56 mg/lit

Sol: PH – 7 → Cl_2 required = 0.7 mg/l

PH – 8 → K = 2.7×10^{-8} what dosage of Cl_2?

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

% of HOCL at given pH,

$$\%HOCL=\frac{1}{1+\frac{K}{H^+}}\times100$$

$$\frac{1}{1+\frac{2.7\times10^{-8}}{1\times10^{-7}}}\times100=78.74\%$$

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

$$\%\ HOCL=\frac{1}{1+\frac{2.7\times10^{-8}}{10^{-8}}}\times100=27.02\%$$

For a given degree of kill (% kill)

Cl_2 dose at any pH= Cl_2 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 Cl_2

$$\%\ HOCL=\frac{1}{1+\frac{K}{H^+}}\times100$$

$$=\frac{1}{1+\frac{2.7\times10^{-8}}{10^{-6}}}\times100$$

= 97.37%

$$Cl_2\text{ dose}=0.70\times\frac{78.74}{97.37}=0.56\text{ mg/lit}$$

11. Ans: (c)

Sol: Percentage removal (%R)

$$=\left(\frac{10^6-10^2}{10^6}\right)\times100=99.99\%$$

$$\log(R)=\log10^6-\log10^2=6-2=4$$

12. Ans: (a)

Sol: Free residual

$$= HOCL + OCL^- = 2mg/lit \text{ as } Cl_2$$

$$2(mg/lit) = Cl_2\left(\frac{moles}{lit}\right) \times Mol.wt \times 1000$$

$$\frac{2}{2 \times 35.5 \times 1000} = Cl_2 \text{ (moles/lit)}$$

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

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

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

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

$$\therefore HOCL = OCL^-$$

$$HOCL + OCL^- = 2mg/lit$$

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

$$\because 2\,OCL^- = 2.816 \times 10^{-5}$$

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

13. Ans: (a)

Sol: Dose of bleaching powder = 2 mg/l

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

Total amount required = Q× Dose of bleaching powder

= 0.5 ×2 = 1 kg/day

14. Ans: (b)

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

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

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

$$= \frac{1}{1+\dfrac{2.5\times10^{-8}}{10^{-7}}} = \frac{1}{1.25} = 0.8$$

15. Ans: (a)

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

C → Concentration of disinfectant

t → detention time (or) contact time

n → dilution factor.

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

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

$\therefore$ $C^n t$ = constant

$\therefore$ $C_1^n t_1 = C_2^n t_2$ = constant

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

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

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

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

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

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

$\therefore$ Total chlorine required for 22 MLD

= $Q_2 \times C_2$

= 22× 2.75 = 60.5 kg/day

16. **Ans: 50.02 m^3**

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

K = 0.145

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

t = 26.979 min

Volume of disinfection unit = Q ×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 mg/m*l*

Cl_2 dose = 0.1 mg/l

Volume of water to be treated = 200 ml

Total amount of Bleaching powder required = ?

$$\text{Bleaching powder required} = \frac{C\ell_2 \text{ dose}}{C\ell_2 \text{ in B.P}}$$

$$= \frac{0.1}{0.3}\frac{\text{mg}/\ell}{\text{mg}/\text{m}\ell}$$

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

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

23. Ans: (d)

Sol: Oxidising power of cl_2 = 35.5

Oxidising power of $NHCl_2$ 21.48

% of chlorine in $NHCl_2$

$$= \frac{\text{oxidising power of NHC}\ell_2}{\text{Oxidising power of C}\ell_2}\times 100$$

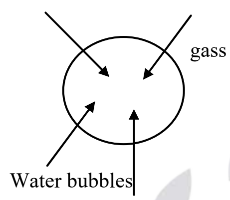
$$= \frac{21.48}{35.5}\times 100$$

= 60%

Chapter- 8
Miscellaneous Water Treatment

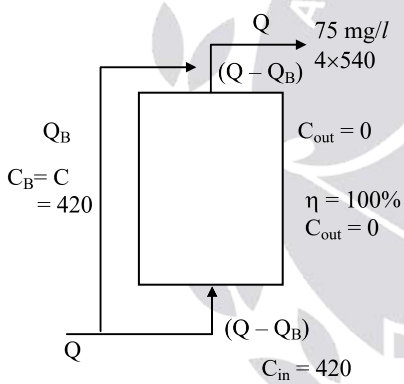
07. Ans: (b)

Sol: liquid-gas system absorption.



10. Ans: 385.714

Sol:



$C_{in} = 420$ mg/l

$C_{out} = 75$ mg/l

$Q = 4 \times 540 = 2160$ lit/day

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

$$= 82.142\%$$

$\eta = 100\%$

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

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

$= 385.714$ lit/day

Flow that can be by passed = 385.714 Lit/day

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

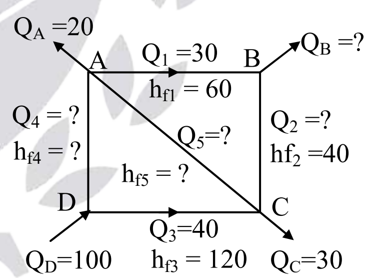
12. Refer to ESE – Volume II(Objective) Book

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

Chapter- 9
Distribution System

03.

Sol:



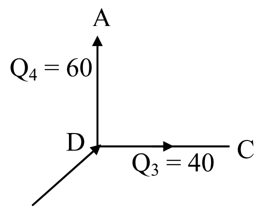
Unknown

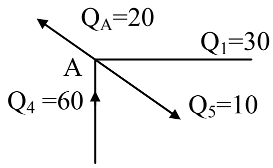
$Q_2 = ?$

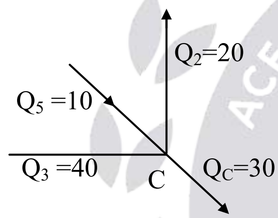
$Q_4 = 60$

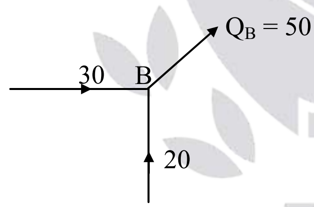
$Q_5 = 10$

$Q_B = ?$

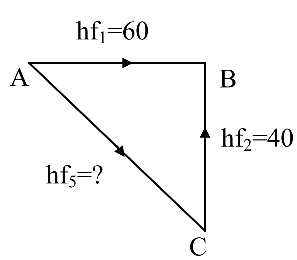








Consider loop ABCA



$\sum H_{ABCA} : 0$

$+hf_1 - hf_2 - h\,f_5 = 0$

$+60 - 40 - hf_5 = 0$

$h_{f5} = 20$

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)

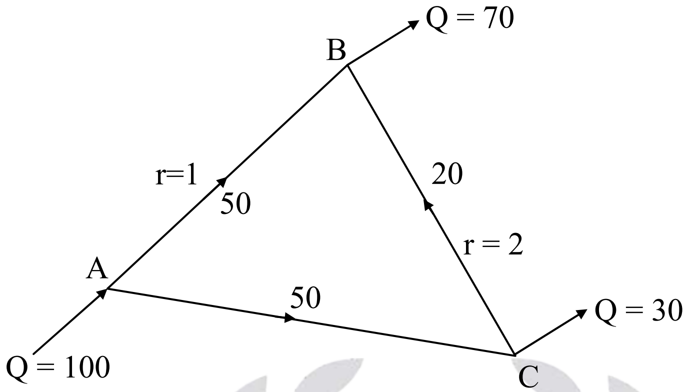
Sol: Water demand at 9th hour = 6.1 ML/hour

Water supply at constant rate = 1.5 m^3/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



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

$\Sigma H_{ABCA} = 0$

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

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

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

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

$r_{AC} = 0.615$

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

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

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

$= 0.41$

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

$= 0.91$ cumecs

03. Ans: 0.1736 m^3/sec, 2.015 m^3/sec

Sol: Population = 1,00,000

Q_{DWF} = Population × percapita × factor

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

$= 15 \times 10^6$ lpcd = 15 MLD

$= 0.1736$ m^3/sec

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

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

$= 14.51$ mm/hr

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

$= 2.015$ m^3/sec

04. Ans: 2.508 m^3/sec

Sol: P = 40000; A = 75 ha

I = 0.70; Factor = 0.70

Q_{DWF} = Population × rate of flow × factor

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

$= 0.0388$ m^3/sec

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

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

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

Combined discharge = 0.0388 + 2.470

= 2.5088 m^3/sec

05. Ans: 0.323 m^3/sec

Sol: A = 1 km^2 = 100 ha

P = 1000 no/ha

For 100 ha, P = 100,000

Rate of flow = 200 *l*pcd

Factor = 0.80

I = 1

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

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

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

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

Q_{WWF} = 0.138 m^3/sec

$Q_{Design} = Q_{DWF} + Q_{WWF}$

= 0.185 + 0.138

= 0.323 m^3/sec

06. Ans: 1.61 m^3/sec

Sol: Given Area (A) = 50 ha

Impression factor (I) = 0.8

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

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

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

t = 50 min

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

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

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

Q = 1.612 m^3/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_{DWF} = Population × Per capita water supply × factor

= 50,000 × 270 × 0.75

= 10.125 MLD

= 0.117 m^3/s

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

$t_c = t_e + t_f = 5+20 = 25$ min

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

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

$= 22.57$ mm/hr

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

$= 4.23$ m^3/s

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

$= 4.35$ m^3/s

$Q = AV$

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

$D = 1.315$ m

03. Ans: (c)

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

The velocity of flowing full and flowing half will be same

V = 1 m/sec

04. Ans: 1 in 449

Sol: Dia = 45 cm = 0.45 m

Population = 30000

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

n = 0.012

Factor = 0.80

Rate of water supply = 150 *l*pcd

S = ?

Q_{DWF} = Population ×per capita water supply × factor

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

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

$Q_{design} = 3.5 \times 0.0416$

$= 0.1456$ m^3/sec

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

Q_{design} = A. V

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

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

$= 0.0022$

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

05. Ans: 1.353 m^3/sec

Sol:

d = 1.25 m

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

Q = ?

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

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

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

Q = 1.35 m^3/sec

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

Sol: $V_{self} = ?$

Dia of sand particles d = 1 mm

S = 2.65

K = 0.1

f = 0.03

n = 0.013

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

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

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

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

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

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

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

07. Ans: 0.36 m, 0.027 m^3/sec, 0.43 m/sec

Sol: Dia of sewer D = ?

n = 0.013

Q = 0.05 m^3/sec

S = 1 in 1000

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

Q = A. 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 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

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

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

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

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

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

V = 0.43 m /sec

08. Ans: (a)

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

V = 0.7 m/s

dia of sewer = 600 mm

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

V = ?

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

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

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

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

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

V = 1.59 m/s

09. Ans: (c)

Sol: Diameter of sewer = 300 mm = 0.30 m

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

$$q=1728\,m^3/day$$

$n = 0.015$

Depth of flow =?

Velocity of flow v = ?

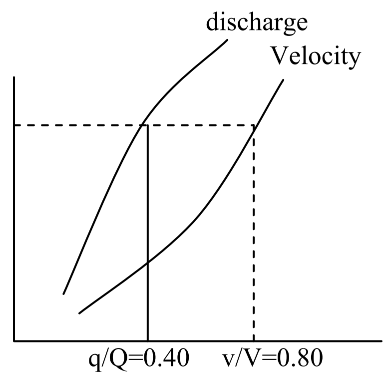
Q = A. V → flow full

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

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

Q = 0.05 m^3/sec = 4320 m^3/day

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



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

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

Depth of flow = 0.50D = 0.5×0.30

= 0.15 m = 150 mm

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

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

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

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

V = 0.568 m/sec

10. Ans: (c)

Sol:

D = 300 mm ;

q = 1728 m^3/day ;

n = 0.015 ;

S = 1/280

To find ‘Q’

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

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

$= 0.05\ m^3/sec$

$= 4320\ m^3/day$

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

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

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

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

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

$\Rightarrow$ $d = 0.5 \times 0.3 = 150$ mm

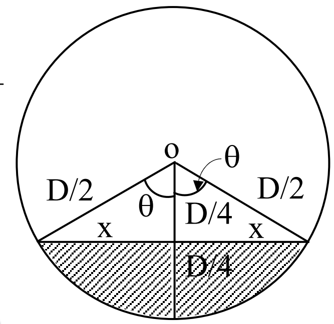
$$\therefore \frac{\vartheta}{V} = 0.8$$

$\vartheta = 0.8 \times 0.708 = 0.57$ 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)

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



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

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

$$\text{Sin}\theta = \frac{x}{\frac{D}{2}} = \frac{\frac{\sqrt{3}}{4}D}{\frac{D}{2}} = \frac{\sqrt{3}}{2}$$

$\theta = 60^o$

Total angle @ $\theta = 120^o$

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

$120^o \rightarrow ?$

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

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

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

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

Chapter- 3
Characteristics of Sewage

01. Ans: 212.19 mg/lit

Sol: Ultimate BOD L_o = ?

6 ml → Waste → $D_o = 0$

294 ml → distilled → $D_0 = 8.6$ mg/l

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

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

$$(D_0)_{Initial} = \frac{V_D(D_o)+V_S(D_o)_S}{V_o+V_S}$$

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

$(D_0)_I = 8.428$ mg/l

$y_5^{20^0C} = [D_o)_I - (D_o)_F] \times D.F$

$$y_5^{20^0C} = [8.428-5.4]\times\frac{300}{6} = 151.4 \text{ mg}/l$$

5 day BOD at 20^0C $y_5^{20^0C}$

$$y_t^{T°C} = L_o\left(1-e^{-K_t\times t}\right)$$

$$y_t^{20^0C} = 151.4 = L_o\left(1-e^{K_{20}\times t}\right)$$

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

L_0 = Ultimate BOD 'L_o' = 212.19 mg/l

02. Ans: (d)

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

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

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

$(D_0)_S = 0.8$ mg/l

$$(D_o)_I = (D_0)_{mixer} = \frac{V_o(D_o)_o+V_S(D_o)_S}{V_o+V_S}$$

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

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

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

03. Ans: (c)

Sol: Fail in finding the BOD of waste water

04. Ans: 90 mg/l

Sol: $y_5^{30^0C}$ = sewage sample = 110 mg/l,

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

$$y_5^{30^0C} = L_o\left(1-e^{-K_t t}\right)$$

$y_5^{20^0C}$ = ?

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

= 2.3 × 0.1

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

$$L_0 = \frac{y_t^{T^0C}}{\left(1-e^{-k_t t}\right)} = \frac{y_5^{30^0C}}{(1-e^{-k_{30}t})}$$

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

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

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

$= 0.364 d^{-1}$

$110 = L_o(1 - e^{-0.364\times5})$

$L_0 = 131.78$ mg/l

$y_5^{20} = L_o\left(1 - e^{-K_{20}\times5}\right)$

$= 131.78(1 - e^{-0.23\times5}) = 90$ mg/l

05. Ans: 246.36 mg/*l*

Sol: $y_1^{30^0C} = 110$ mg/l, $y_5^{20^0C} = ?$

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

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

$y_1^{30^0C} = L_o\left(1 - e^{-0.364\times1}\right)$

$110 = L_o(1 - e^{-0.364\times1})$

$L_o = 360.5$ mg/l

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

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

$= 360.5(1 - e^{-0.23\times5}) = 246.36$ mg/l

06. Ans: 304000

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

compute daily 5 day O_2 demand

Total strength of waste = Q × y

= 80 × 285

= 22800 kg/day

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

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

Population equivalent = 304000 persons

07. Ans: 93.72%

Sol: $S_r = 100(1\text{-}0.794^t)$

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

$S_r = 93.72\%$

08. Ans: 1%

Sol: $BOD_5 = 600$ mg/l,

K = 0.23/d (base e); $K = 0.23 d^{-1}$, $L_0 = ?$

BOD_u remain unoxidised after 20 days =?

$y_5^{20^0C} = L_o\left(1 - e^{-K_t t}\right)$

$600 = L_o(1 - e^{-0.23\times5})$

$L_o = 878.01$ mg/l

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

$= 878.01 \times e^{Kt}$

$= 878.01 \times e^{-0.23\times20}$

$= 8.82$ 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

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

$y_5^{20} = [(D_o)_I - (D_o)_F] \times DF$

$= [9.2 - 6.9] \times 60$

$= 138$ mg/*l*

$y_5^{20} = [9.1 - 4.4] \times \frac{300}{10} = 141$ mg/*l*

$BOD_{avg} = \frac{138+141}{2} = 139.5$ mg/*l*

10. Ans: (c)

Sol: $y_5^{20} = L_0(1 - e^{-Kt})$

$K = 0.01 h^{-1}$ (base e)

$= 0.01 \times 24\ d^{-1} = 0.24\ d^{-1}$

$190 = L_0(1 - e^{-0.24\times5})$

$L_o = \frac{190}{(1 - e^{-0.24\times5})} = 271.89$ mg/*l*

11. Ans: (d)

Sol: $y_5^{20°C} = 180$ mg/*l*

$k_{20} = 0.18\ d^{-1}$

$k_T = k_{20}\,(1.047)^{T-20}$

= to exert same BOD in 2.5 days

$y_5^{20°C} = y_{2.5}^{T°C} = 180$ mg/*l*

$l_o(1 - e^{-k_{20}\times5}) = l_o(1 - e^{-k_t\times2.5})$

$k_{20} \times 5 = k_{20}\,(1.047)^{T-20} \times 2.5$

$(1.047)^{T-20} = 2$

$(T - 20)\ l_n\ 1.047 = ln_2$

$T = 35°\ C$

12. Ans: (c)

Sol: $BOD_3 = 75$ mg/*l*, $K = 0.345 d^{-1}$ (base e)

BOD = 10 days = ?

$y_3^{20} = L_o(1 - e^{-0.345\times3})$

$L_o = 116.31$ mg/*l*

$L_t = 116.31(1 - e^{-0.345\times10})$

$L_t = 112.61$ mg/*l*

$L_o - L_t = 116.31 - 112.61 = 3.7$ mg/*l*

14. Ans: (b)

Refer to ESE Volume-II (objective) Book

16. Ans: (b)

Sol: $y_5^{20°C} = [(DO)_I - (DO)_F] \times DF$

$$= [8.5 - 5.5] \times \frac{100}{2} = 150 \text{ mg}/l$$

18. Ans: (c)

Sol: $y = 162$ mg/l

$Q = 1000 \text{ m}^3/\text{day}$

$Q = 1000 \times 1000$ $l$pcd = 1 MLD

Per capita BOD = 80 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)

Sol: $[(DO)]_I = 8$ mg/l, $(DO)_F = 2$ mg/l

$$\text{Dilution factor} = \frac{300}{2} = 150 \text{ m}l$$

$$5 \text{ days BOD} = [(DO)_I - (DO)_F] \times \text{D.F}$$

$$= (8-2) \times 150$$

$$= 900 \text{ mg}/l$$

20. Ans: (a)

Refer to ESE Volume-II (objective) Book

21. Ans: (c)

Sol: $y_5^{20} = 250$ mg/l, T = 30^0C, t = ?,

$y_5^{30} = 250$ mg/l

$$y_5^{20} = y_5^{30}$$

$$L_o\left(1 - e^{K_{20}\times 5}\right) = L_o\left(1 - e^{-K_{30}\times t}\right)$$

$$K_{20}\times 5 = K_{30}\times t$$

$$K_{20}\times 5 = K_{20}(1.047)^{30-20}\times t$$

$$t = \frac{5}{(1.047)^{10}} = 3.158 = 3.3 \text{ days}$$

23. Ans: (a)

Sol: $y_5^{20°C} = y_3^{27°C} = y_4^{30°C}$

$$L_\circ\left(1 - e^{-K_{20}\times 5}\right) = L_\circ\left(1 - e^{-K_{27}\times 3}\right) = L_\circ\left(1 - e^{-K_{30}\times 4}\right)$$

$$K_{20} \times 5 = K_{20} \times (1.047)^{27-20} \times 3 = K_{20}(1.047)^{30-20} \times 4$$

$$5 \simeq 4.13 \simeq 6.33$$

5 days 20°C BOD equal to 3 days 27°C BOD

25. Ans: 128.1 mg/l

Sol: $y_5^{20°} = ?$

$$y_7^{20°C} = 150 \text{ mg}/\ell$$

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

$$150 = L_o\left(1 - e^{-0.23\times 7}\right)$$

$$L_o = 187.47 \text{ mg}/l$$

$$y_5^{20°C} = 187.47\left(1 - e^{-0.23\times 5}\right)$$

$$y_5^{20°} = 128.11 \text{ mg}/\ell$$

26. Ans: (c)

Sol: $L_o = 20$ mg/l

$K = 0.15\ d^{-1}$

$$\%\text{ BOD exerted in 7days} = \frac{y_7}{L_o}\times 100$$

$$= \frac{L_o\left[1-e^{-Kt}\right]}{L_o}\times 100$$

$$= \frac{20\left[1-e^{-0.15\times 7}\right]}{20}\times 100$$

$$= 65\%$$

$$\%\text{ BOD remaining after 7days} = \frac{L_7}{L_o}\times 100$$

$$= \frac{L_o e^{-kt}}{L_o}\times 100$$

$$= \frac{20\times e^{-0.15\times 7}}{20}\times 100$$

$$= 35\%$$

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 m, Q = 720 m^3/hr = 70 m^3/min

L = 12 m, B = 1.50 m

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

$$= \frac{720}{12\times 1.50} = 40\ \text{m}^3/\text{hr}$$

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

$$= \frac{12\times 1.5\times 0.8\times 60}{720} = 1.2\ \text{min}$$

04. Ans: (b)

Sol: Q=3 m^3/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 mm

V_s = ?

$\upsilon = 1\times 10^{-2}$ cm^2/sec $= 1\times 10^{-6}$ m^2/sec

For laminar flow condition

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

$$V_s = \frac{9.81\times(2.70-1)\times(0.21\times10^{-3})^2}{18\times1\times10^{-6}}$$

V_s = 0.04089 m/sec = 4.089 cm/sec

06. Ans: (b)

Sol: L = 7.5 m; H = 0.9m

V_H = 0.3 m/sec

$$\nu = \frac{\mu}{\rho} = \frac{1.002\times10^{-3}}{1000}$$

$= 1.002\times10^{-6}\ m^2/sec$

For η = 100%, $\frac{L}{V_H} = \frac{H}{V_S}$

V_S = 0.036 m/sec

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

$$0.036 = \frac{9.8}{18}(2.5-1).\frac{d^2}{(1.002\times10^{-6})}$$

d = 0.21 mm

07. Ans: (d)

Sol: Q = 5005 m^3/d

V_0 = 35 m^3/m^2/d

Surface area $= \frac{Q}{V_0} = \frac{5005}{35}$

$$\frac{\pi}{4}d^2 = 143$$

d = 13.5 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: $y_i = 180$ mg/l, $V_L = 550$ gm of BOD per 1 cu.m of volume

$Q = 50 \times 10^6\ l$/d = 50 MLD, V = ?

$$\text{V.L.R.} = \frac{Qy_i}{V}$$

$$550 \times 10^{-3} = \frac{50\times180}{V}$$

$$550 \times 10^{-3} \times V = 9000$$

$$V = 16363\ m^3$$

02. Ans: (d)

Sol: $Q = 50 \times 10^6\ l$/d = 50 MLD, $y_i = 180$ mg/l,

$\frac{F}{M} = 0.5\ d^{-1}$, X = 1800 mg/$l$, V = ?

$$\frac{F}{M} = \frac{Qy_i}{VX}$$

$$0.5 = \frac{50{,}000\times180}{1800\times V} \Rightarrow V = 10{,}000 m^3$$

03. Ans: (a)

Sol: X = 2000 mg/l

$$\text{SVI} = \frac{V}{X} = \frac{\text{Volume occupied in ml}}{\text{MLSS in gm}}$$

$$= \frac{176}{\frac{2000}{10^3}} = \frac{176}{2} = 88\ ml/gm$$

Common Data for Question Nos. 04 & 05

04. Ans: (c)

Sol: Q = 35,000 m^3/d, V = 10900 m^3,

$y_1 = 250$ mg/l, $y_e = 20$ mg/l

MLSS = 2500 mg/l

$$\text{Aeration period} = \frac{V}{Q} = \frac{10{,}900}{\frac{35000}{24}} = 7.47\ \text{hrs}$$

05. Ans: (b)

Sol: $\frac{F}{M} = \frac{Q(y_i)}{VX}$

$$= \frac{35000(250)}{10{,}900\times2500}\ \frac{m^3/d/(mg)ln}{m^3/mgl}$$

$$= 0.32\ d^{-1}$$

06. Ans: (c)

Sol: $\eta_{BOD} = \frac{y_i - y_e}{y_i}\times100$

$$= \frac{250-20}{250}\times100 = 92\%$$

07. Ans: (a)

Sol: Sludge age $\theta_c = \frac{VX}{Q_wX_U + Q_eX_e}$

$$= \frac{10900\times2500}{220\times9700+(35000-220)30}$$

= 8.57 days

08. Ans: (c)

Sol: SVI = 88 ml/gm, X_u = ?

$$X_u = \frac{10^6}{SVI} = \frac{10^6}{88} = 11364 \text{ mg}/l$$

09. Ans: (c)

Sol: X = 1000mg/l, Volume = 200 ml

$$SVI = \frac{V}{X} = \frac{200}{1} = 200 \text{ m}l/\text{gm}$$

10. Ans: (d)

Sol: V = 400m^3, X= 1000 mg/l

Total amount of MLSS in aeration tank = VX

$$= 400 \times 1000 \times (1000 \times 10^{-6}) = 400 \text{ kg}$$

12. Ans: 6.3 hrs, 109.5, 0.33d^{-1}, 2054.3m^{3}day

Sol: L= 30 m, B = 14 m, H = 4.3 m

Q = 0.796 m^3/s = 6877.44 m^3/day

y_1 = 130 mg/l,

X = 2100 mg/l

MLVSS = 1500 mg/l,

Volume occupied = 230 ml/lit

$$\frac{F}{M} = \frac{Qy}{VX}$$

$$= \frac{6877.44 \times 130}{1806 \times 1500} = 0.33d^{-1}$$

$$DT = \frac{V}{Q} = \frac{1806}{\frac{6877.44}{24}} = 6.3 \text{ hrs}$$

$$SVI = \frac{230}{2.1} = 109.5 \text{ m}l/\text{day}$$

$$\frac{Q_r}{Q} = \frac{X}{\frac{10^6}{SVI} - X}$$

$$\frac{Q_r}{6877.4} = \frac{2100}{\frac{10^6}{109.5} - 2100}$$

$$= 2054.3 \text{ m}^3/\text{day}$$

13. Ans: (c)

Sol: X = 2800 mg/l carried out 1 lit sample

V = 200 ml

$$SVI = \frac{200}{2.8} = 71.4 \text{ m}l/\text{gm}$$

Common data for Q 14 & 15

14. Ans: (c)

Sol: Given,

Q = 500 m^3/h

y_i = 150 mg/l

y_e = 10 mg/l

D T = 8 hours

Q_C = 240 hours

V = 4000 m^3

X = 2000 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)

Sol: $Q_C = \dfrac{\text{mass of solid reactors}}{\text{mass of solid wasted per day}}$

$Q_C = \dfrac{VX}{\text{mass of solid wasted per day}}$

Mass of solid wasted/day $= \dfrac{VX}{Q_C}$

$= \dfrac{4000 \times 2000}{\frac{240}{24}} \times 1000 \times \dfrac{1}{10^6}$

= 800 kg/day

16. Ans: (d)

Sol: X = 4000 mg/*l* = 4 gm/*l*

Volume = 200 m*l*

$SVI = \dfrac{\text{Volume}}{X} = \dfrac{200}{4}$

SVI = 50 m*l*/gm

17. Ans: (c)

Sol: MLSS normally kept any where between 1500- 3000 mg/*l*

19. Ans: i. (2000 m^3) ii. (4.8 hrs)

iii. (86.66%) iv. 0.75 kg/day/m^3

v. 600 kg/day vi. 60 m^3/day

vii. 100

viii. 0.428

ix. 4285.71 m^3/day

Sol: **Given:**

Flow rate (Q) = 10,000 m^3/day

Inflow BOD (y_i) = 150 mg/lit

Outflow BOD (y_E) = 20 mg/lit

MLSS (X) = 3,000 mg/lit

We know

$\dfrac{F}{M} = \dfrac{Qy_i}{VX}$

$VX = \dfrac{10{,}000 \times 150}{0.25} = 6 \times 10^6$

(I) Volume of aeration tank

$V = \dfrac{6 \times 10^6}{3 \times 10^3}$ ($\because$ X = 3000 mg/*l*it)

$\therefore$ Volume = 2000 m^3

(II) Aeration period $= \dfrac{2000}{10{,}000} \times 24$

= 4.8 hours

(III) B.O.D removal efficiency

$= \dfrac{y_i - y_E}{y_i} \times 100$

$= \dfrac{150 - 20}{150} \times 100$

η = 86.66%

(IV) Volumetric loading rate

$V_L = \dfrac{Qy_i}{V} = \dfrac{10{,}000 \times 150}{2000} \times \dfrac{1000}{10^6}$

= 0.75 kg/day/m^3

(V) Mass of sludge wasted per day

$MCRT = \theta_c = \dfrac{VX}{Q_w x_u + Q_e x_e}$

$10 = \dfrac{200m^3 \times 300mg/L \times \frac{100L}{m^3} \times \frac{1kg}{10^9 mg}}{\text{mass of sludge wasted per day}}$

$\therefore$ Mass of sludge wasted per day = 600 kg/day

(VI)

Volume of sludge wasted per day

$Q_w x_u + Q_e x_e$ = mass of sludge wasted per day

$Q_w(10{,}000) + (Q - Q_w)(0) = 600$ kg/day

$$Q_w = \frac{600}{10{,}000} = 0.06\,\text{MLD}$$

$$Q_w = 0.06 \times \frac{10^6\,L}{1mL} \times \frac{1m^3}{1000L}$$

$Q_w = 60\ m^3/day$

(VII) $$\text{S.V.I} = \frac{10^6}{X_w} = \frac{10^6}{10{,}000} = 100\ \text{ml/gm}$$

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

$Q_R = 0.4285 \times 10{,}000$

$Q_R = 4285\ m^3/day$

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 = $\dfrac{\text{Total } O_2 \text{ to be supplied}}{O_2 \text{ transfer capacity of aerator}}$

$$= \frac{\frac{768}{24}}{0.8} \frac{kg/hr}{kg/Hp.hr}$$

Total O_2 to be supplied = total BOD

= 20 HP

Chapter- 6
Trickling Filters

01. Ans: (c)

Sol: $y_i = 200$ mg/l

$y_e = 40$ 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 kg/m^3/day

$y_i = 150$ mg/l

$y_e = ?$

$$\eta = \frac{100}{1 + 0.0044\sqrt{\frac{Q.y_i}{V.F}}}$$

1 ha.m = 10^4 m^3

$1\ m^3 = 10^{-4}$ ha. m

$\frac{Qy_i}{V}$ kg of BOD/day/ ha.m

OLR = 0.175×10^4 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 mg/l

03. Ans: 2.14m, 5142.85m³, 84.45%, 23.3 mg/l

Sol: Q = 6 MLD

y_i = 150 mg/l

OLR = 175 gm/m^3/day

SLR = 2500 l/m^2/day

Depth of TF = ?

Vol. of TF = ?

η = ?

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 m

organic loading Rate $= \frac{Q.y_i}{V}$

$$V = \frac{150 \times 6}{175 \times 10^{-3}}$$

V = 5142.85 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) OLR = $175 \times 10^{-3} \times 10^4$ kg/ha. m/day

OLR = 1750 kg/ha. m/day

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

$$\eta = \frac{100}{1 + 0.0044\sqrt{175 \times 10^{-3} \times 10^4}}$$

η = 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 mg/l

04. Ans: 633 m³

Sol: Single stage TF

y_e = 20 mg/l; y_i = 120 mg/l

Q = 2200 m^3/day

R = 4000 m^3/day

V = ?

∵ Recirculation is there it is high rate TF

$$\frac{R}{I} = \frac{4000}{2200} = 1.81$$

$$F = \frac{1 + \frac{R}{I}}{\left(1 + 0.1\frac{R}{I}\right)^2} = 2.017$$

$Q = 2200\ m^3/day = 2.2\ MLD$

$$\eta = \frac{y_i - y_e}{y_i} \times 100$$

$$\eta = \frac{120-20}{120} \times 100 = 83.33\%$$

$$83.33 = \frac{100}{1 + 0.0044\sqrt{\frac{2.2 \times 120}{V \times 2.017}}}$$

$V = 0.0633$ ha. m

$V = 633\ m^3$

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, 16.68m^3/day

Sol: Q = 4.5 MLD

(i) Total dry solids = Q ×suspended solids

$= 4.5 \times 275$

$= 1237.5$ kg/day

Mass of sludge produced $= \frac{100}{(100 - P_1)} M$

Solids concentration in sludge

$$= \frac{55}{100} \times 275 = 151.25\ mg/l$$

Total mass of dry solids produced/day

$$= \frac{100}{(100 - \eta_C)} \times M$$

$$= \frac{100}{(100-96)} \times 680.625$$

$= 17015.625$ kg/day

(ii) $\frac{\rho_{sludge}}{\rho_w} = S_{sludge}$

$\rho_{sludge} = 1.02 \times 1000 = 1020\ kg/m^3$

$$\rho_{sludge} = \frac{\text{mass of sludge}}{\text{Volume of sludge}}$$

$$1020 = \frac{17015.625}{\text{Volume of sludge}}$$

$$\text{Volume of sludge} = \frac{17015.625}{1020}$$

$= 16.68\ m^3/day$

03. Ans: (c)

Sol: $\frac{V_2}{V_1}=\frac{100-P_1}{100-P_2} = \frac{100-99}{100-96} = 0.25\%$

% of reduction is volume = 100 –25 = 75%

05. Ans: (d)

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%

$$\frac{100}{S_{sludge}} = \frac{\%\,water}{S_{water}} + \frac{\%\,Solids}{S_{solids}}$$

$$\frac{100}{S_{sludge}} = \frac{98}{1} + \frac{2}{2.2}$$

$S_{sludge} = 1.011$

$\rho_{sludge} = 1.011 \times 1000 = 1011\,kg/m^3$

08. Ans: (b)

Sol: After thickening $V_2 = \frac{V_1}{2}$

$V_2 = \frac{(100-P_1)V_1}{(100-P_2)} \Rightarrow 100-P_2 = 200-196$

$P_2 = 96\%$

($\because$ Solid content is 4%)

12. Ans: 1.011, 1011 kg/m^3

Sol: Given solids content = 2%

Let ρ_{solid} be the mass density of solids

Solids again contain 70% volatile & 30% of non-volatile

$$\therefore \text{we know} = \frac{100}{S_{solids}} = \frac{70}{S_{volatile}} + \frac{30}{S_{non-volatile}}$$

$$\Rightarrow \frac{100}{S_{solids}} = \frac{70}{2.2} + \frac{30}{2.7}$$

$\Rightarrow S_{solids} = 2.329$

$\simeq 2.4$

Now let mass density of sludge as ρ_s and specific gravity as S_s

$$\therefore \frac{100}{S_s} = \frac{2}{S_{solids}} + \frac{98}{S_{water}}$$

$$\Rightarrow \frac{100}{S_s} = \frac{2}{2.4} + \frac{98}{1}$$

$\Rightarrow S_s = 1.011$

$\rho_s = 1011\,kg/m^3$

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%

$$V = \frac{100 - P_1}{100 - P_2} \times V_1$$

$$= \frac{100 - 94}{100 - 84} \times 14$$

$= 5.25\ m^3$

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

$Q = 200 \times 150 = 30\ m^3/d$

Volume = Q × DT

$$= \frac{30}{24} \times 24 = 30\ m^2$$

$L \times B \times H = 2B \times B \times 1.5 = 30$

B = 3.16 m

L = 6.32 m

L × B = 6.32 m × 3.16 m

02. Ans: 0.6 m

Sol: Rate of sludge production

= 30 $l$it/person/year

Cleaning period = 2 yrs

Depth of sludge zone = ?

$Q_{sludge} = 30 \times 200 \times 10^{-3}$

$= 6\ m^3/year$

Volume $= 6 \times 2 = 12\ m^3$

$$\text{depth} = \frac{12}{6.32 \times 3.16} = 0.6\ m$$

03. Ans: (a) 9.6 m^3 (b) 12 m^3

Sol: Population = 120

Per capita sewage flow = 150 lpcd

Size of septic tank = 4m × 2m

liquid depth = 1.5 m

Detention period =?

$Q = 120 \times 150 = 18\ m^3/day$

$$DT = \frac{V}{Q} = \frac{4 \times 2 \times 1.5}{18} = 0.67\ \text{days}$$

(a) Rate of sludge production

= 40 lit/person/year

Cleaning period = 2 yrs

Volume of sludge produced = ?

$Q_{sludge} = 120 \times 40 = 4.8\ m^3/year$

Volume of sludge $= 4.8 \times 2 = 9.6\ m^3$

(b) Percolation capacity of pit

= 1500 lit/m^3/day

Volume of soak pit =?

Volume of soak

$$\text{pit} = \frac{Q}{\text{Percolation capacity}}$$

$$= \frac{120 \times 150}{1500} = 12\ m^3$$

06. Ans: (d)

Sol: $V = 7\ m^3$

No. of users = 5

R.S.P = 70 lit/capita/year

Volume of sludge zone $= \frac{V}{2} = \frac{7}{2}$

Cleaning interval = cleaning period

Volume of sludge zone = RSP × no. of user × C.P

$$\frac{7}{2} = 70 \times 10^{-3} \times 5 \times C.P$$

$$C.P = \frac{7/2}{70 \times 10^{-3} \times 5}$$

$= 10$ years

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

$= 0.8 \times y_i = 10{,}000 \times 100 \times 40 \times 10^{-3}$

$y_i = 500$ mg/lit

$$\text{Surface area of pond} = \frac{Q \times y_i}{\text{BOD loading rate}}$$

$$= \frac{0.8 \times 500}{200} = 2 \text{ ha}$$

Surface area $= 2\text{ ha} = 2 \times 10^4\ m^2$

$$L = 4B$$

$$L \times B = 2 \times 10^4$$

$$4B \times B = 2 \times 10^4$$

$$B = \sqrt{\frac{2 \times 10^4}{4}} = 70.71\ m$$

$L = 4 \times 70.71 = 282.84$ m

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

$$= \frac{282.84 \times 70.71 \times 2}{0.8 \times 10^6 \times 10^{-3}} = 50 \text{ days}$$

$$\eta = 80 = \frac{y_i - y_e}{y_i} \times 100$$

$$80 = \frac{500 - y_e}{500} \times 100$$

$y_e = 500 - 400 \Rightarrow 100$ mg/l

02. Ans: L = 244.9 m, B = 61.23m, H = 1m

Sol: P = 10,000; sewage flow = 150 $l$pcd

$$Q = \frac{10000 \times 150}{10^6} = 1.5\,\text{MLD}$$

$y_i = 300$ mg/l, $y_e = 30$ mg/l,

OLR = 300 kg/ha/d

$k_D = 0.23 d^{-1}$, L:B = 4:1

$$\therefore D.T. = \frac{1}{0.23}\times \ln\frac{300}{30} = 10 \text{ days}$$

$$\therefore \text{Surface area} = \frac{Qy_i}{OLR} = \frac{1.5\times 300}{300} = 1.5\text{ha}$$

$L\times B = 1.5\times10^4\ m^2$

$4B\times B = 1.5\times10^4$

$B = 61.23$ m

$\therefore L = 4\times 61.23 = 244.92$ m

Vol of oxidation pond = $Q\times DT$

$$= \frac{1.5\times10^6}{10^3}\times 10 = 15000\,m^3$$

$$\text{Depth of pond, } H = \frac{\text{Vol. of pond}}{\text{Surface area of pond}}$$

$$= \frac{15000}{15000} = 1\text{m}$$

05. Ans: (c)

Sol: Q = 10000 × 200 = 2 MLD, y = 300 mg/l

Organic loading rate = 310 kg/day/ha

$$\text{Surface area of pond} = \frac{Q\ y_i}{\text{BOD loading rate}}$$

$$= \frac{2\times 300}{310} = 1.93 \backsimeq 2 \text{ ha}$$

Chapter- 10
Disposal of Sewage Effluents

01. Refer to ESE Volume-II (objective) Book

03. Ans: (c)

Sol: Waste water $(DO)_w = 2$ mg/l

$Q_W = 1.10\ m^3/sec$

$(DO)_R = 8.3$ mg/l

$Q_R = 8.70\ m^3/sec$

$$(DO)_{mix} = \frac{(DO)_w.Q_w + (DO)_R.Q_R}{Q_w + Q_R}$$

$$(DO)_{mix} = \frac{2\times1.10 + 8.3\times 8.70}{1.10+8.70}$$

$(DO)_{mix} = 7.6$ mg/l

04. Ans: 13.85 mg/*l*, 20.27 mg/*l* , 5.85 mg/*l*

Sol: $Q_w = 12000\ m^3/d$, temp = 20^0C,

$y_w = 50$ mg/l

$(DO)_w$ = concentration = 2 mg/l

$Q_R = 40,000\ m^3/d$, $y_R = 3$ mg/l,

$(DO)_R = 7$ mg/l, temp = 20^0C

K = 0.23 (to the base in decay curve)

$$y_{mix} = \frac{Q_R y_R + Q_w y_w}{Q_R + Q_w}$$

$$= \frac{12000\times50+40{,}000\times3}{12{,}000+40{,}000} = 13.84\,\text{mg/lit}$$

$$(DO)_{mix} = \frac{Q_R(DO)_R + Q_w(DO)_w}{Q_R + Q_w}$$

$$= \frac{12{,}000\times2+40{,}000\times7}{12{,}000+40{,}000}$$

$$= 5.85\ \text{mg}/l$$

$$y_{mix} = L_o(1-e^{-k\times t})$$

$$13.85 = L_o(1-e^{-0.23\times5}) = \frac{13.85}{(1-e^{-0.23\times5})}$$

$$L_o = 20.27\ \text{mg}/l$$

06. Ans: 100 ha

Sol: Q = 8 MLD,

Land capable of consuming

= 80000 lit/ha/day

$$\text{Area of land} = \frac{Q}{\text{consuming capacity of soil}}$$

$$= \frac{8\times10^6}{80000}$$

= 100 ha

07. Ans: 45000 lit/ha/day

Sol: A = 140 ha, Q = 4.5 MLD

$$\text{Area of land} = \frac{Q}{\text{consuming capacity of soil}}$$

$$140 = \frac{4.5}{\text{c.c.of soil}}$$

C.C. of soil × 140 = 4.5

Let area of land required of sewage application = x. ha

Extra land provided for rest and rotation

$$= \frac{40}{100}x = 0.4\,x$$

Total land required = x + 0.4x

1.4x = 140

x = 100

$$\text{Consuming capacity of soil} = \frac{Q}{\text{area of land}}$$

$$= \frac{4.5\times10^6}{100}$$

= 45000 lit/ha/day

08. Ans: (b)

Sol: $Q_w = 8640\ m^3/d$, temp = 25^0C,

$$Q_w = \frac{8640}{24\times60\times60} = 0.1\ m^3/s$$

$Q_R = 1.2\ m^3/s$, temp = 15°C

$Q_R = 1.2 \times 24 \times 60 \times 60 = 103680\ m^3/d$

$$t_{mix} = \frac{Q_R t_R + Q_w t_w}{Q_R + Q_w}$$

$$= \frac{1.2\times15+0.1\times25}{1.2+0.1} = 15.76^0\,C$$

09. Ans: (c)

Sol:

River	**Waste water stream**
$Q_R = 12\ m^3/sec$	$Q_w = 2m^3/sec$
$(L_0)_R = 5\ mg/l$	$(L_0)_w = 90\ mg/l$

$$(L_o)_{mix} = \frac{Q_R(L_0)_R + Q_W(L_0)_W}{Q_R + Q_w}$$

$$= \frac{12\times5+2\times90}{12+2} = 17.142\ mg/l$$

$$Q_{mix} = Q_R+Q_w = 12+2 = 14\ m^3/sec$$

$$\text{Velocity} = \frac{Q_{min}}{c/s\,area} = \frac{14}{50} = 0.28\,m/sec$$

Time taken by the river to travel 10km

$$= \frac{10\times1000}{0.28}\times\frac{1}{24\times60\times60}$$

$$T = 0.413\ \text{days}$$

Ultimate BOD at 10 km d/s = $L_t = L_0\,e^{-kt}$

$$k = 0.25\ /day$$

$$L_{0.413} = 17.142\ e^{-0.25\times0.413} = 15.459\ mg/lit$$

$$\simeq 15.46\ mg/l$$

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

$$= \sum\frac{P_iE_i}{100}$$

$$= \frac{15\times4650+45\times16750+10\times16300+10\times32600 + 10\times6500+5\times18600+5\times700}{100}$$

$$= 14740\ kJ/kg$$

(ii) Energy on dry basis = Energy as discarded

$$\times\ \frac{100}{100-\%m.c}$$

$$= 14740\times\frac{100}{100-21}$$

$$= 18658.22\ kJ/kg$$

(iii) Energy content on an ash – free dry basis

$$= \frac{100}{100 - \%m.c - \%ash}$$

$$= \frac{100}{100-21-5} \times 14740$$

= 19918.9 kJ/kg

02. Ans: (b)

Sol: $$\frac{100}{\rho_{Msw}} = \frac{\%F.W}{\rho_{Fw}} + \frac{\%DA}{\rho_{DA}} + \frac{\%pla}{\rho_p} + \frac{\%w\ \&\ y}{\rho_{w\&y}}$$

$$= \frac{50}{300} + \frac{30}{500} + \frac{10}{65} + \frac{10}{125}$$

$$= \frac{100}{\rho_{Msw}} = 0.46 \Rightarrow \frac{100}{0.46}$$

$\rho_{Msw} = 217.1\ kg/m^3$

04. Ans: (d)

Sol: 50 g of CO_2, 25 g = CH_4, 1 million people, rate of 500 ton/day

120 parts of MSW release 50 parts of CO_2 and 25 parts CH_4 1 part of MSW release

$\frac{75}{120}$ = 0.625 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

$$= \frac{\text{Green house gas}}{\text{population of community}}$$

$$= \frac{312.5}{10,00,000} \times 1000 \times 1000$$

= 312.5 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 solid waste = Night soil + garbage

= 35t+40 t = 75 t

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 kg/day

Solid waste generator per annum

= 130000×365

= 47450000 kg/Annum

$$\text{Volume} = \frac{\text{mass}}{\text{density}}$$

$$V = \frac{47450000}{650}$$

$V = 73000\ m^3$

$$\text{Area} = \frac{\text{Volume}}{\text{depth}} = \frac{73000}{5}$$

$A = 14600\ m^2$

$= 1.46$ ha

13. Ans: (a)

Sol: $$\frac{100}{\rho_{sludge}} = \frac{c_1}{\rho_1} + \frac{c_2}{\rho_2} \Rightarrow \rho_{sludge} = \frac{100}{\dfrac{c_1}{\rho_1} + \dfrac{c_2}{\rho_2}}$$

14. Ans: 13.6875

Sol: Solid waste generated

$= 2 \times 10^5 \times 25 \times 365 \times 2$

$= 3.65 \times 10^9$ kg

Volume of un-compacted

$$S_w = \frac{3.65\times10^9}{100} = 36.5 \times 10^6\ m^3$$

$$\text{Volume of compacted solid waste} = \frac{36.5\times10^6}{4}$$

$= 9.125 \times 10^6\ m^3$

$$\frac{\text{Compacted fill}}{\text{Compacted solid waste}} = 1.5$$

Volume of land fill (compacted fill)

$= 9.125 \times 10^6 \times 1.5$

$= 13.6875 \times 10^6$ million m^3

Chapter- 12
Air Pollution and Control

05. Ans: (b)

Sol: $\longrightarrow \boxed{ESP_1} \longrightarrow \boxed{ESP_2} \longrightarrow$

$\eta_1 = 80$ $\quad$ $\eta_2 = 65\%$

Let 'x' be concentration of particles in blue gas

Particles removed by ESP_1

$= 80\%\ (x) = 0.8x$

Particles remain in blue gas after ESP_1

$= 0.2x$

Particles removed by ESP2

$= 65\%\ (0.2x) = 0.13x$

Particles remained in blue gas after ESP_2

$= 0.07x$

Overall removed

$$= \frac{x - 0.07x}{x} \times 100 = 93\%$$

06. Ans: (d)

Sol: $CHCl_3 = 12 + 1 + 3\times35.5$

$= 119.5$ gm molecular.

Concentration $= 0.4\ \mu g/m^3 @ 273^0$ k

$T_1 = 273^0$ k $\qquad T_2 = 293^0$k

$P_1 = 1 \qquad P_2 = 1$

$V_1 = 22.4$ lit/ mol $\quad V_2 = ?$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{22.4}{273} = \frac{V_2}{293} \Rightarrow V_2 = 24.04\,\text{lit/mol}$$

$$\mu g/m^3 = \frac{\text{PPM} \times \text{gm.mole.} \times 10^3}{\text{lit/mol}}$$

$$0.4 = \frac{\text{PPM} \times 119.5 \times 10^3}{24.04 \times 10^{-3}}$$

$$\text{PPM} = 8.047 \times 10^{-5} \times 10^3$$

$$[\because 1\text{billion} = 10^9] = 0.08$$

Parts per billion

$$= 8.047 \times 10^{-5} \times 10^3 = 0.08$$

09. Ans: (a)

Sol: Dry air cools at 9.8^0 per km

$\approx 10^0$ km

For $\frac{1}{2}$ km $\rightarrow 5^0$ fall

Final temperature at 500 m elevation

$= 40^0 - 5^0 = 35^0$c

10. Ans: (c)

Sol: Volume of air sampled

= avg. rate of sampling × duration of sampling

$$= \frac{1.5 + 1.4}{2} \times (24 \times 60) = 2088\,m^3$$

$$\text{TSP} = \frac{\text{final weight of filter paper} - \text{Initial weight of filter paper}}{\text{Volume of air sampled}}$$

$$= \frac{10.283 - 9.787}{2088} = 2.375 \times 10^{-4}\ \text{gm/m}^3$$

$$= 2.375 \times 10^{-4} \times 10^6 = 237.547\ \mu g/m^3$$

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)

Sol: Lapse rate = $\frac{dt}{dz} = \frac{T_2 - T_1}{Z_2 - Z_1}$

$$= \frac{15.70 - 21.25}{444.4}$$

ALR 1 m = -0.0126^0/2m

Per 100 m = 0.0126 × 106

CLR = 1.261^0/100m

CLR > ALR → Super adiabatic

23. Ans: 0.011268

Sol: $\frac{P}{RT} = 41.6\,\text{mol}/m^3$

$$\frac{RT}{P} \times 10^3 = \text{constant} = 24.038$$

$$1\mu g/m^3 = \frac{24.038}{M \times 10^3}\ \text{ppm}$$

$$30\ \mu g/m^3 \text{ of } SO_2 = \frac{24.038}{64 \times 10^3} \times 30$$

$$= 0.011268\ \text{ppm}$$

24. Ans: (b)

Sol: $v = \frac{2}{60} m/sec$

Total surface area of bags required $= \frac{Q}{v}$

$$\frac{10}{2/60} = 300\ m^2$$

Surface area of each bag $= \pi dH$

$= \pi \times 0.45 \times 7.5$

Number of bags required $= \frac{300}{\pi \times 0.45 \times 7.5}$

$= 28.29 \simeq 29$

25. Ans: 8012.38

Sol: η of ESP is given by

$\eta = 1 - e^{\frac{-AW}{Q}}$

when $\eta = 96\%$ $A = 5600\ m^2$

$\eta = 97\%$ $A = 6100\ m^2$

$\eta = 99\%$ $A = ?$

$0.96 = 1 - e^{\frac{-5600\times w}{185}} \Rightarrow W = 0.1063$ m/sec

$0.99 = 1 - e^{\frac{-A\times 0.1063}{185}} \Rightarrow A = 8012.38\ m^2$

plate area of collector $A = 8012.38\ m^2$

26. Ans: 592.88

Sol: % sulphur in coal = 2

Rate of coal consumption = 30 kg/min

% sulphur in ash = 6

SO_2 emission $= \left(\frac{t}{year}\right) = ?$

Total sulphur produced = Rate of Coal consumption ×% sulphur in Coal

$$30 \times \frac{2}{100} kg/min \times \frac{365\times 24\times 60}{1000} \times t/year$$

(Convert in to tonn/year)

SO_2 emission of gas

$$= 30 \times \frac{2}{100} \times \frac{365\times 24\times 60}{1000}\left(\frac{100-6}{100}\right)$$

= 296.45 /year

$S + O_2 \rightarrow SO_2$

$S = 32$

$SO_2 = 64$

32 Parts of sulphur = 64 parts of SO_2

1 Part of $SO_2 = \frac{64}{32}$ parts of SO_2

296.4 t/year of sulphur produce

$= \frac{64}{32} \times 296.4$ t/year of SO_2

SO_2 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: $L_1 = 60\text{ dB} = 20\log_{10}\frac{P_1}{P_0} = 20\log_{10}\frac{P_1}{20}$

$P_1 = P_2$

$P_{rms} = \sqrt{(20000)^2 + (20000)^2} = 28284.27\text{ dB}$

$\text{Total SPL} = 20\log_{10}\frac{P_{rms}}{P_0}$

$= 20\log_{10}\frac{28284.27}{20}$

$= 63\text{ dB (or)}$

(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: $I = 20\log_{10}\times \frac{1}{4}\Sigma\left(10^{\frac{20}{20}} + 10^{\frac{56}{20}} + 10^{\frac{66}{20}} + 10^{\frac{42}{20}}\right)$

$= 56.8\text{ dB}$

04. 87.3 dB

$$\ell_{eq} = 10\log_{10}\Sigma\left(10^{\frac{\ell_i}{10}} \times T_i\right)$$

$$T_i = \frac{t_i}{T}$$

Total time = 10 + 80 + 5 = 95

$$\ell_{eq} = 10\log_{10}\left(10^{\frac{80}{10}} \times \frac{10}{95} + 10^{\frac{60}{10}} \times \frac{80}{95} + 10^{\frac{100}{10}} \times \frac{5}{95}\right)$$

$= 87.3\text{ dB}$

05. Ans: (c)

Sol: $P = 2000\ \mu\text{ bar}$

Particular = $10^5\text{ N/m}^2\text{cPa)}$

$1\ \mu\text{ bar } 10^{-6} \times 10^5\text{ N/m}^2 = 0.1\text{ Pa}$

$\Rightarrow 10^{-6} \times 10^5 \times 10^6 = 10^5\ \mu\text{Pa}$

$1\ \mu\text{ bar} = 10^6\text{ MPa}$

$1 = 20\log_{10}\frac{2000\times10^5}{20}$

$= 140\text{ dB}$

08. Ans: (a)

Sol:

$20\log_{10}\frac{P}{P_{ref}} = L$

$P = 0.0002\ \mu$

$L = 20\log_{10}\frac{0.0002\times10^5}{20} = 0\text{ dB}$

09. Ans: (c)

Sol:

50 dB + 50 dB

50 + 3 = 53 dB

10. Ans: 74 dB

Sol: $L_1 = 80$ dB, $r_1 = 20$ m

$L_2 = ?$, $r_2 = 40$ m

$$L_2 = L_1 - 20\log_{10}\left(\frac{r_2}{r_1}\right)$$

$$L_2 = 80 - 20\log_{10}\left(\frac{40}{20}\right)$$

$L_2 = 73.98$ dB $\simeq$ 74dB