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Environmental Engineering

Text Book : Theory with worked out Examples
and Practice Questions



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Environmental Engineering

(Solutions for Text Book Practice Questions)

Water Supply Engineering

01. Population Forecasting & Water Demands

01. Ans: (c)

Sol:

Year	Population	Per decade increased in Population
1970	40000	
1980	46000	6000
1990	53000	7000
2000	58000	5000

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

$$P_{2010} = P_0 + n\bar{x}$$

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

$$n = 1$$

$$P_{2010} = 58000 + 1 \times 6000$$

$$P_{2010} = 64000$$

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 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

$\bar{y} = 500$ per decade

$P_{2020} = ?$

$P_{1990} = 50000$ (given)

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

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

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

$$P_{2020} = 68000$$

05. Ans: 743900

Sol:

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

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

$$\bar{x} = 111300$$

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

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

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

$P_{2020} = ?$

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

$$P_{2020} = 695200 + 2 \times 111300 + \frac{2(2+1)}{2} (-57966.67)$$

$$P_{2020} = 734900$$

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

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

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

$$40,000 = 28,000 + n \times 8000$$

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

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

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

$$r_0 = 11.5$$

$$P_n = P_0 \left[1 + \frac{r_0 - \bar{D}}{100} \right] \left[1 + \frac{r_0 - 2\bar{D}}{100} \right] \dots \left[1 + \frac{r_0 - n\bar{D}}{100} \right]$$

P_0 = 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

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

$$\bar{D} = 1.635$$

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

$$P_n = P_0 \left[1 + \frac{r_0 - \bar{D}}{100} \right] \left[1 + \frac{r_0 - 2\bar{D}}{100} \right] \left[1 + \frac{r_0 - 3\bar{D}}{100} \right]$$

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

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

$$= 100765.29 \approx 100765$$

$\therefore$ Population for the year 2020 by decreasing rate of growth = 100765

09. Ans: (c)

Sol: $P = 1102500$

$$r = 5\%$$

$$n = 2 \text{ years}$$

the population of city '2' years ago is given

$$P = P_0 \left[1 + \frac{r}{100} \right]^n$$

$$1102500 = P_0 \left[1 + \frac{5}{100} \right]^2$$

$$P_0 = 1000000$$

03. Quality of Water

01. Ans: (d)

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

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

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

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

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

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

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

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

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

14. Ans: (d)

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

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

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

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

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

$$\text{P}\bar{\text{H}} = 7.47$$

15. Ans: (c)

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

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

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

16. Ans: (a)

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

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

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

Sample B,

$V_B = 700 \text{ ml}$

$(\text{pH})_B = 5$

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

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

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

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

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

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

17. **Ans: (d)**

Sol: $\text{CO}_3^{--} = 90 \text{ mg/l}$

$\text{HCO}_3^- = 61 \text{ mg/l}$

$$\text{TA} = \text{CO}_3^{--} \times \frac{50}{30} + \text{HCO}_3^- \times \frac{50}{61}$$

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

$\text{TA} = 200 \text{ mg/l as CaCO}_3$

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

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

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

19. **Ans: (a)**

Sol: $\text{PH} = 9$

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

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

$\text{OH}^- \text{ mol/lit}$

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

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

$$\text{OH}^- = 0.17 \times \frac{50}{17} = 0.50 \text{ mg/lit as CaCO}_3$$

27. **Ans: (d)**

Sol: $\text{TA} = 250 \text{ mg/l as CaCO}_3$

$\text{TH} = 350 \text{ mg/l as CaCO}_3$

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

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

$\text{NCH} = \text{TH} - \text{CH} = 350 - 250$

$\text{NCH} = 100 \text{ mg/l as CaCO}_3$

28. **Ans: (c)**

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

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

$\text{TH} \approx 179 \text{ mg/l as CaCO}_3$

Common data for Q 29 & 30

29. **Ans: (a)**

Sol: TH in mg/lit as CaCO_3

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

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

$= 1500 \text{ mg/lit as CaCO}_3$

30. **Ans: (c)**

Sol: Alkalinity in mg/lit CaCO_3

$$= \text{HCO}_3^- \text{ in mg/lit} \times \frac{50}{61} + \text{CO}_3 \text{ in mg/lit} \times \frac{50}{30}$$

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

$= 1750 \text{ mg/lit as CaCO}_3$

Common data for Question Nos. 31. & 32

 31. **Ans: (c)**

Sol: $TH = 100 \times \frac{50}{20} + 6 \times \frac{50}{12}$
 $= 275 \text{ mg/lit as } CaCO_3$

 32. **Ans: (a)**

Sol: $Alkalinity = 250 \times \frac{50}{61}$
 $= 204.9 \approx 205 \text{ mg/lit as } CaCO_3$

 33. **Ans: (d)**

Sol: Tomato juice pH = 4.1

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

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

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

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

 34. **Ans: (d)**

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

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

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

$$H^+ = \frac{10^{-14}}{10^{-8.6}} = 10^{-5.4}$$

$$pH = \log_{10} \left(\frac{1}{H^+} \right) = \log_{10} \frac{1}{10^{-5.4}}$$

$$pH = 5.4$$

 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

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

$$MPN = 7 \times 10 = 70$$

 37. **Ans: (b)**

Sol: Mol. Wt of $CO_3 = 12 + 3 \times 16 = 60$

Mol. Wt. of Ca = 40

60 parts of CO_3 required = 40 parts of Ca

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

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

$$= 60 \text{ mg/l of Ca}$$

 38. **Ans: (c)**

Sol: PH = 9.25

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

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

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

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

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

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

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

$$OH^- = 0.302 \text{ mg/l as } CaCO_3$$

39. **Ans: (d)**

Sol: $TON = \frac{A+B}{A}$
 $TON = \frac{187.5 + 12.5}{12.5}$
 $TON = 16$

40. **Ans: (b)**

Sol: $OH^- = 17 \text{ mg/l}$
 $OH^- (\text{mol/l}) = \frac{(OH^-) \text{mg/l}}{\text{Mol. wt. of } OH^- \times 1000}$
 $OH^- = \frac{17}{17 \times 1000} = 10^{-3} \text{ mol/lit}$
 $[H^+][OH^-] = 10^{-14} \text{ mol/lit}$
 $H^+ = \frac{10^{-14}}{10^{-3}} = 10^{-11} \text{ mol/lit}$
 $pH = \log_{10} \frac{1}{H^+} = \log_{10} \frac{1}{10^{-11}}$
 $pH = 11$

41. **Ans: (b)**

Sol: $Ca^{2+} = 4 \text{ m.eq/lit}$
 $Mg^{2+} = 1 \text{ m eq/lit}$
 $HCO_3^- = 3.5 \text{ m. eq/lit}$
 $TH = Ca^{2+} * 50 + Mg^{2+} * 50$
 (where Ca & Mg are in m.eq/lit)
 $= 4 \times 50 + 1 \times 50 = 250 \text{ mg/l as } CaCO_3$
 $TA = CO_3 * 50 + HCO_3 * 50$
 (where CO_3 & HCO_3 in m.eq/lit)
 $= 0 + 3.5 \times 50 = 175 \text{ mg/l as } CaCO_3$
 $TH > TA$
 $\therefore CH = TA = 175 \text{ mg/l as } CaCO_3$
 $NCH = TH - CH = 250 - 175$
 $= 75 \text{ mg/l as } CaCO_3$

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

Sol: $W_1 = 98.42 \text{ gm}$
 $W_2 = 98.484 \text{ gm}$
 $W_3 = 98.462 \text{ gm}$

(i) Total solids (TS) $= \frac{W_2 - W_1}{V}$
 $TS = \frac{98.484 - 98.42}{100} \times 10^6$

$= 640 \text{ mg/l}$
 (ii) Volatile solids $= \frac{W_2 - W_3}{V}$
 $= \frac{98.484 - 98.462}{100} \times 10^6$
 $= 220 \text{ mg/l}$

(iii) Fixed solids $= \frac{W_3 - W_1}{V}$
 $= \frac{98.462 - 98.42}{100} \times 10^6$
 $= 420 \text{ mg/l}$

04. Plain Sedimentation

Common data for Qs. 1 & 2

01. **Ans: (b)**

Sol: $B = 6 \text{ m}, L = 15 \text{ m}, H = 3 \text{ m}$

$Q = 2 \text{ MLD}$

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

02. Ans: (d)

Sol: Detention time is

Volume of setting tank = $Q \times D.T$

$$DT = \frac{6 \times 15 \times 3}{2 \times 10^6} = \frac{270}{83.33} = 3.24 \text{ hrs}$$

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

Common data question for Q3 and Q4

03. Ans: (c)

Sol: $Q = 1.8 \text{ MLD}$

$D.T = 4 \text{ hours}$

$V = ?$

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

$$\text{Volume of tank} = Q \times DT$$

$$= 75 \times 4 = 300 \text{ m}^3$$

04. Ans: (b)

Sol: $SOR = 500 \text{ lit/hr/m}$, $L:B = 4:1$, $L = ?$

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

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

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

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

$$L^2 = 150 \times 4$$

$$L = 24.49 \text{ m}$$

05. Ans: 0.0112 m/sec

Sol: $V_H = ?$ $L = 60 \text{ m}$, $H = 3 \text{ m}$

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

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

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

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

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

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

06. Ans: (c)

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

Settling velocity = 20 m/day

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

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

07. Ans: (a)

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

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

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

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

08. Ans: 27.08

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

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

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

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

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

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

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

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

$$= \frac{9.02 \times 10^{-4}}{3.33 \times 10^{-3}} \times 100 = 27.08\%$$

Common Data for Qs. 09 & 10

09. Ans: (a)

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

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

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

10. Ans: (d)

$$\begin{aligned} \text{Sol: Weir loading} &= \frac{Q}{\text{length of weir}} \\ &= \frac{13000}{\pi \times 26} = 159 \text{ m}^3/\text{day/m} \end{aligned}$$

11. Ans: 44.5, 14.83 & 0.47

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

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

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

$$\begin{aligned} V_s &= \frac{g(G-1)d^2}{18 \times v} \\ &= \frac{9.81(2.3-1) \times (0.05 \times 10^{-3})^2}{18 \times 1.01 \times 10^{-6}} \end{aligned}$$

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

For 100% removal

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

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

$$L : 3B = 660.011$$

$$L \times B$$

$$3B \times B = 660.011$$

$$3B^2 = 660.011$$

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

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

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

$$\frac{44.49 \times 14.83 \times 3}{\frac{100 \times 10^6}{24 \times 10^3}} = 0.47 \text{ hr}$$

12. 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 -- ?, $\rho = 2.65 \text{ g/cc}$,

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

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

$$= \frac{100000}{100 \times 50} = 20 \text{ m}^3/\text{m}^2/\text{day}$$

For 100% removal $V_s = V_0$

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

$$= \frac{20}{24 \times 60 \times 60} = 2.31 \times 10^{-4}$$

$$S = \frac{\rho_p}{\rho_w} = \frac{2.65}{1} = 2.65$$

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

$$2.31 \times 10^{-4} = \frac{9.81(2.65-1) \times d^2}{1.836 \times 10^{-5}}$$

$$d = 1.61 \times 10^{-5} \text{ mm}$$

$$d = 1.61 \times 10^{-2} \text{ m}$$

13. Ans: (c)

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

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

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

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

$$V_o = \frac{Q}{\text{S.area}} = \frac{8000}{900} = 8.889 \text{ m}^3/\text{day/m}^2$$

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

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

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

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

Proportion of particle removed ' η '

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

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

Common data for Question Nos. 14 & 15

14. Ans: (a)

Sol: $L = 20 \text{ m}$, $B = 10 \text{ m}$, $H = 3 \text{ m}$, $Q = 4 \text{ MLD}$,

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

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

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

$$= \frac{4 \times 10^6 \times 10^3}{20 \times 10} = 20 \text{ m}^3/\text{m}^2/\text{day}$$

15. Ans: (b)

Sol: $\eta = 100\%$

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

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

$$= 2.65 \times 998.2$$

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

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

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

16. Ans: (b)

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

$V_{S2} = 0.2 \text{ mm/s}$,

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

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

Particle	Percentage (P_i)	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	$\eta_3 = \frac{1}{0.5} \times 100 = 20$

Overall removal = $\sum P_i \eta_i$

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

$$= 56\%$$

17. Ans: (b)

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

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

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

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

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

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

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

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

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

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

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

18. Ans: 3.1214

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

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

$$G = 2.65$$

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

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

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

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

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

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

19. Ans: 22.576

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

$$V_0 = 40 \text{ m}^3/\text{m}^2/\text{day} = 40 \text{ m/day}$$

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

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

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

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

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

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

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

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

20. Ans: 112.66

Sol: Surface over flow rate

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

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

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

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

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

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

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

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

21. Ans: (b)

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

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

$$DT = ?$$

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

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

22. 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%

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

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

23. Ans: (b)

Sol:

Particle	Settling velocity (m/hr)	Initial concentration (mg/l)	$n \times C_{in} \text{ mg/l}$
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

05. Coagulation

Common Data Question 1 & 2

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 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

CO_2 gas = ?

Total alum requirement/day

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

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

$\text{Al}_2(\text{SO}_4)_3 = 18 \text{ H}_2\text{O} + \text{Ca}(\text{HCO}_3)_2$

$\rightarrow 3\text{CaSO}_4 + 2\text{Al}(\text{OH})_3 + 6\text{CO}_2 + 18\text{H}_2\text{O}$

Molecular weight of alum = 666

Molecular weight of $6\text{CO}_2 = 6[\text{c}(\text{O}_2)]$

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

$= 264$

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

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

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

Sol: $Q = 12 \text{ MLD}$

Dosage of ferrous sulphate 10 mg/l

Total quantity of ferrous sulphate and lime-?

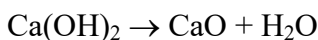
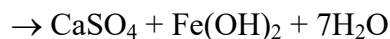
$= \text{FeSO}_4 \cdot 7\text{H}_2\text{O}$

Total quantity of ferrous sulphate req/day

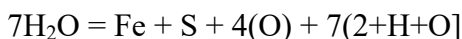
$= Q \times \text{dosage of ferrous sulphate}$

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

$\text{FeSO}_4 \cdot 7\text{H}_2\text{O} + \text{Ca}(\text{OH})_2$



Molecular weight of FeSO_4 .



Molecular weight of $\text{CaO} = 56$

278 parts of ferrous sulphate required

= 56 parts of CaO

1 part of ferrous sulphate required

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

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

$$= 2.14 \text{ mg/l}$$

Total lime as CaO required/day

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

$$= 12 \times 2.014$$

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

05. Ans: 3780 kg

$$\text{Sol: } Q = 3.5 \text{ m}^3/\text{min} = 5.04 \text{ MLD}$$

Dose of alum = 25 mg/l

Total alum required in kg/day

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

$$= 5.04 \times 25 = 126 \text{ kg/day}$$

Monthly alum requirement = 126×30

$$= 3780 \text{ kg}$$

06. Ans: (b)

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

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

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

07. Ans: (d)

$$\text{Sol: } Q = 28800 \text{ m}^3/\text{d}; \quad \rho_w = 1000 \text{ kg/m}^3$$

$$v = 10^{-6} \text{ m}^2/\text{sec}; \quad G = 900 \text{ s}^{-1}$$

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

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

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

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

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

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

08. Ans: 1613.92 watts

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

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

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

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

$$L = 2B$$

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

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

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

$$0.80B^3 = 1000$$

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

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

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

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

10. Ans: (b)

Sol:

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

$$V_0 = 0.2 \text{ mm/sec};$$

$$d = 3.5 \text{ m}$$

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

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

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

06. Filtration

01. Ans: 35.35 m, 17.67 m

Sol: $P = 50,000$ person

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

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

$$Q = 50,000 \times 150 = 7500000 \text{ lit/day}$$

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

$$= 1.8 \times 7500000$$

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

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

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

$$= \frac{135 \times 10^5}{24 \times 180} \frac{\text{lit/hr}}{\text{lit/hr/m}^2} = 3125 \text{ m}^2$$

No. of filters in operations = 5

(1 act as stand by)

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: 11

Sol: Treated water $Q = 10$ MLD

$$= 10 \times 10^3 \text{ m}^3/\text{day}$$

Rate of filtration RDF = 200 lit/hr/m²

$$= 200 \times 10^{-3} \times 24 \text{ m}^3/\text{day/m}^2$$

Total area required to treat water

$$= \frac{Q}{\text{RDF}} = \frac{10 \times 10^3}{200 \times 10^{-3} \times 24}$$

$$= 2083.33 \text{ m}^2$$

$$\text{Area of each filter} = 20 \times 10 \text{ m}^2$$

$$\text{No. of filters required} = \frac{\text{Total area of filters}}{\text{area of each filter}}$$

$$= \frac{2083.33}{200}$$

$$= 10.41 \approx 11 \text{ numbers}$$

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

Sol: $Q = 24$ MLD, $\text{ROF} = 5 \text{ m}^3/\text{hr/m}^2$,

$$\text{L:B} = 2 : 1$$

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

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

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

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

$$\text{L: B} = 200$$

$$2B \times B = 200$$

$$B^2 = \frac{200}{2} = \sqrt{\frac{200}{2}} = 10 \text{ m}$$

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

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 $\text{ROB} \times$

$\text{DOB} \times \text{area}$

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

% of filter water used in back wash

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

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

04. Ans: 9.48 m, 4.74 m, 0.225 m³/sec

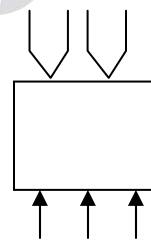
Sol: $Q = 0.25 \text{ m}^3/\text{sec}$, No. of filters = 4,

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

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

$$\text{L : B} = 2 : 1$$

$$\text{L} = ?, \text{B} = ?$$



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

$$= \frac{0.25 \times 60 \times 60}{6} = 180 \text{ m}^2$$

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

$$\text{L} \times \text{B} = 45$$

$$2B \times B = 45$$

$$2B^2 = 45$$

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

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

$$= 10 \times 45 = 450 \text{ liter/sec} = 0.45 \text{ m}^3/\text{sec}$$

$$\begin{aligned} \text{Back wash water flow rate OB} &= \text{velocity} \\ (V_B) \times \text{Area of each filter} \\ &= 10 \times 45 = 450 \text{ lit/sec} \\ &= 0.45 \text{ m}^3/\text{sec} \end{aligned}$$

There are two troughs

$$\begin{aligned} \text{Flow through each wash water} &= \frac{Q}{2} \\ &= \frac{0.45}{2} = 0.225 \text{ m}^3/\text{sec} \end{aligned}$$

05. Ans: 0.27 m

Sol: $V_l = i_r = 3.0 \text{ m/hr}$

$$L = 0.6 \text{ m} \quad \phi = 0.8$$

$$d = 0.5 \text{ mm} \quad n = 0.4$$

$$S = 2.68 \quad v = 1 \times 10^{-6} \text{ m}^2/\text{sec}$$

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

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

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

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

$$= 271.75$$

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

$$\begin{aligned} &= \frac{271.75 \times 0.6 \left(\frac{3}{60 \times 60} \right)^2}{9.81 \times 0.5 \times 10^{-3}} \times \frac{(1-0.4)}{0.4^3 \times 0.8} \\ &= 0.251 \text{ m} \end{aligned}$$

06. Ans: 0.032 m/sec, 0.6258 m

Sol: $d = 0.65 \text{ mm}$, $G = 2.66$, $n = 0.42$,

$$z = 65 \text{ cm} = 0.65 \text{ m}$$

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

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

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

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

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

$$\frac{1.53}{z} = \frac{1-0.42}{1-n_e}$$

$$1.5(1-n_e) - 1 - 0.42 \Rightarrow 1.5 - 1.5 n_e = 0.58$$

$$n_e = \frac{1.5 - 0.58}{1.5}$$

$$n_e = 0.613$$

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

Head loss during back wash h_b

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

$$= 0.6258 \text{ m}$$

07. Ans: (a)

$$\text{Sol: } \frac{1}{z} \ln \frac{100}{100 - \eta_1} = \frac{1}{z_2} \ln \frac{100}{100 - \eta_2}$$

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

$$Z_2 = ?$$

$$\frac{1}{0.05} \ln \frac{100}{100 - 90} = \frac{1}{z_2} \ln \frac{100}{100 - 99}$$

$$46.06 = \frac{1}{z_0} \times 4.606$$

$$\Rightarrow z_2 = \frac{4.606}{46.06}$$

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

Common data for Question Nos. 08 & 09

08. Ans: (c)

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

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

$$\begin{aligned} \text{Total area} &= \frac{Q}{\text{ROF}} = \frac{0.5}{200} \\ &= \frac{0.5}{24 \times 60 \times 60} \\ &= 216 \text{ mm}^2 \end{aligned}$$

09. Ans: (c)

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

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

10. Ans: 144 m³/day/m²

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

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

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

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

$$= 14 - 2 = 12$$

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

11. Ans: 7.53

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

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

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

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

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

$$\begin{aligned} \text{Amount of water filtered/day} &= \text{ROF} \times \text{DOF} \times \\ &(\text{L} \times \text{B}) \end{aligned}$$

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

$$\text{Amount of water recycled \& reused}$$

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

$$\text{Duration of maturation} \times (\text{L} \times \text{B})$$

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

$$\text{Percentage increase in filtered water}$$

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

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

12. Refer Previous GATE solutions Book
(Cha-6, Two marks 7th Question-Pg: 773)

13. Refer Previous GATE solutions Book
(Cha-6, Two marks 9th Question-Pg: 774)

07. Disinfection

01. Ans: 51.2 sec

Sol: $N_0 = 10^6$

$$N_t = 100$$

$$\ln\left(\frac{100}{10^6}\right) = -6 \times 10^{-3} \times 30 \times t$$

$$t = 51.16 \text{ sec}$$

02. Ans: (c)

Sol: Population = 20,000 at a per capita demand
= 150 lit/day

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

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

$$\text{Bleaching powder} = 0.2 \text{ mg/l}$$

$$\text{Cl}_2 = 0.2 \text{ ppm} = 0.2 \text{ mg/l}$$

$$\text{Ca(Ocl)}_2 = 30\% \text{ available Cl}_2$$

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

$$= 3 \times 0.66 = 1.98 = 2 \text{ kg/day}$$

03. Ans: (c)

Sol: $\text{Cl}_2 = 20,000 \text{ Cu m}$

$$8 \text{ kg. residual after 10 min} = 0.15 \text{ mg/l}$$

$$Q = 20,000 \text{ m}^3/\text{day}$$

$$\text{Total Cl}_2 \text{ used} = 8 \text{ kg/day}$$

$$\text{Residual Cl}_2 = 0.15 \text{ mg/l}$$

$$\text{Dose of Cl}_2 = ?$$

$$\text{Demand} = ?$$

$$\text{Total Cl}_2 = Q \times \text{design of Cl}_2$$

$$8 = 20,000 \times \text{dose of Cl}_2 \text{ MLD}$$

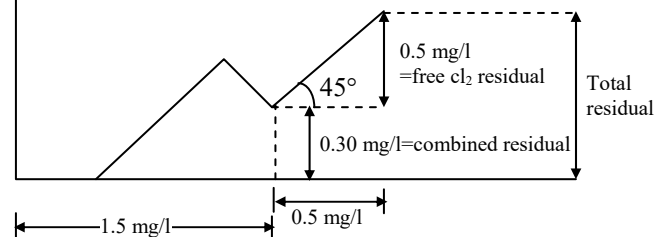
$$\text{Dose of Cl}_2 = \frac{8}{20} = 0.4 \text{ mg/l}$$

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

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

04. Ans: (b)

Sol:



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

05. Ans: (b)

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

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

$$H^+ = 2.43 \times 10^{-7}$$

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

$$\Rightarrow P^H = 6.614$$

08. Ans: (d)

Sol: Cl_2 available in Bleaching powder (B.P) =
0.3 mg/ml

Cl_2 dose = 0.1 mg/l

Volume of water to be treated = 200 ml

Total amount of Bleaching powder required
= ?

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

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

Total bleaching powder required =
bleaching powder dose $\times$ Volume of water

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

09. Ans: 3.2 min

Sol: Residual = 0.6 mg/l, $K = 3 \times 10^{-2}$ per sec
 $t = ?$

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

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

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

Solving

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

$$= 3.2 \text{ min}$$

10. Ans: (c)

Sol: Percent removal (%R)

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

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

11. Ans: (a)

Sol: Free residual

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

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

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

$$Cl_2 = 2 \text{ mg / lit} = 2.816 \times 10^{-5} (\text{moles / lit})$$

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

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

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

$$\therefore HOCL = OCL^-$$

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

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

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

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

12. Ans: (b)

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

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

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

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

13. 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.

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

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

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

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

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

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

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

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

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

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

$$\therefore \text{Total chlorine required for 22 MLD}$$

$$= Q_2 \times C_2$$

$$= 22 \times 2.75$$

$$= 60.5 \text{ kg/day}$$

14. Ans: 50.02 m³

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

$$K = 0.145$$

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

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

Contact time "t" = detention time

$$= 7.0358 \text{ min}$$

$$\text{Volume of disinfection unit} = Q \times Dt$$

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

15. Ans: (d)

Sol: Oxidising power of $\text{Cl}_2 = 35.5$

Oxidising power of $\text{NHCl}_2 = 21.48$

% of chlorine in NHCl_2

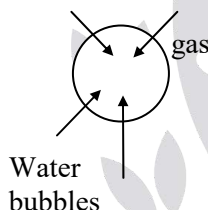
$$= \frac{\text{oxidising power of } \text{NHCl}_2}{\text{Oxidising power of } \text{Cl}_2} \times 100$$

$$= \frac{21.48}{35.5} \times 100 = 60\%$$

08. Miscellaneous Water Treatment

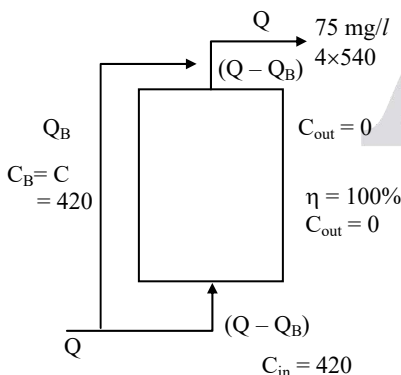
05. Ans: (b)

Sol: liquid – gas system absorption.



08. Ans: 385.714

Sol:



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

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

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

$$\eta = \frac{C_{in} - C_{out}}{C_{in}} \times 100 = \frac{420 - 75}{420} \times 100 = 82.142\%$$

$$\eta = 100\%$$

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

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

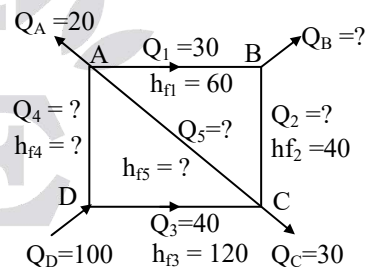
$$= 385.714 \text{ lit/day}$$

Flow that can be by passed = 385.714 Lit/day

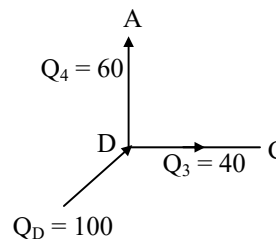
09. Distribution System

03. Ans:

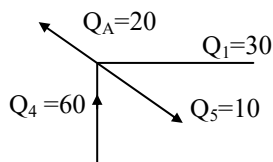
Sol: $Q_B = 50;$ $Q_2 = 20;$ $Q_4 = 60$
 $Q_5 = 10;$ $h_{f5} = 20;$ $h_{f4} = 100$



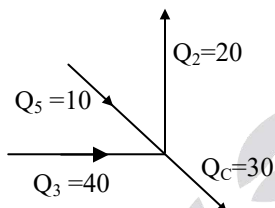
Consider junction 'D', unknown is Q_4



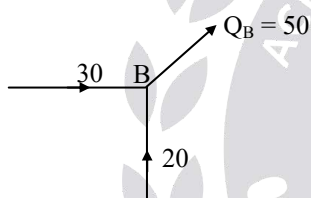
Consider junction A, unknown is Q_5



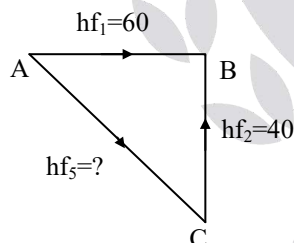
Consider junction C, unknown is Q_2



Consider junction B, unknown is Q_B



Consider loop ABCA, $\Sigma H_{ABCA} : 0$

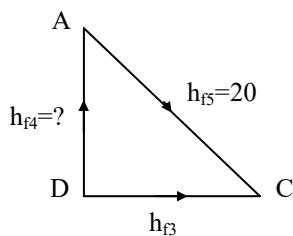


$$+h_{f1} - h_{f2} - h_{f5} = 0$$

$$+60 - 40 - h_{f5} = 0$$

$$h_{f5} = 20$$

Consider loop ACDA



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

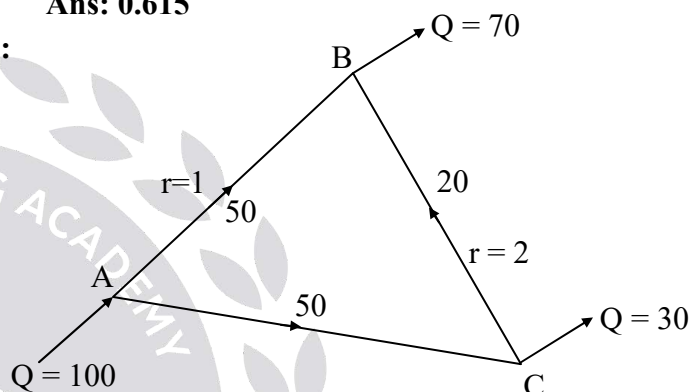
$$+h_{f5} - h_{f3} + h_{f4} = 0$$

$$20 - 120 + h_{f4} = 0$$

$$h_{f4} = 100$$

06. Ans: 0.615

Sol :



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

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

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

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

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

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

$$r_{AC} = 0.615$$

07. 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

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

Waste Water Engineering

01. Introduction to Waste Water Engineering and Estimation of DWF & WWF

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:

$$\text{Intensity}(I) = \frac{\sum A_i \times I_i}{A}$$

$$= \frac{(40)(0.8) + (30)(0.2) + (30)(0.1)}{40 + 30 + 30}$$

$$= 0.41$$

$$Q_{wwF} = \frac{\text{AIR}}{360} \text{ Where } A = 16 \text{ ha}$$

$$I = 0.41$$

$$R = 5 \text{ cm/hr} = 50 \text{ mm/hr}$$

$$\therefore Q_{wwF} = \frac{(16)(0.41)(50)}{360} = 0.911 \text{ m}^3/\text{sec}$$

03. Ans: 0.1736 m³/sec, 2.015 m³/sec

Sol: Population = 1,00,000

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

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

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

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

$$Q = \frac{\text{AIR}}{360} \Rightarrow R = \frac{25.4a}{t_c + b} = \frac{25.4 \times 40}{50 + 20}$$

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

$$= \frac{100 \times 0.5 \times 14.15}{360} = 2.015 \text{ m}^3/\text{sec}$$

04. Ans: 2.508 m³/sec

Sol: P = 40000

$$A = 75 \text{ ha}$$

$$I = 0.70$$

$$\text{Factor} = 0.70$$

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

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

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

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

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

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

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

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

05. Ans: 0.323 m³/sec

Sol: $A = 1 \text{ km}^2 = 100 \text{ ha}$; $P = 1000 \text{ no/ha}$

Rate of flow = 200 lpcd

Factor = 0.80

$P = 100000$

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

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

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

$R = 0.5 \text{ mm/h}$

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

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

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

02. Design of Sewers

02. Ans: 1.311 m

Sol: $A = 150 \text{ ha}$

$P = 50,000$

$V = 3.2 \text{ m/sec}$ [$t_c = t_e + t_f = 5 + 20 = 25 \text{ min}$]

$t_e = 5 \text{ min}$

$t_f = 20 \text{ min}$

$Q = 270 \text{ lt/d/c}$

Impermissibility factor = 0.45

Factor = 0.75

$$Q_{\text{DWF}} = 50000 \times 270 \times 0.75 \\ = 0.117 \text{ m}^3/\text{sec}$$

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

$$\left[R = \frac{25.4a}{t_c + b} \right] \\ = \frac{25.4(40)}{25 + 20} = 22.57 \\ = 4.23$$

$$Q = Q_{\text{DWF}} + Q_{\text{WWF}} = 0.117 + 4.23 \\ = 4.34 \text{ m}^3/\text{sec}$$

$Q = AV$

$$4.34 = \frac{\pi}{4} \times D^2 \times 3.2$$

$$D^2 = \frac{4 \times 4.34}{\pi \times 3.2} = 1.72$$

$$D = \sqrt{1.72} = 1.311 \text{ m}$$

03. Ans: (c)

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

The velocity of flowing full and flowing half will be same

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

04. Ans: 1 in 449

Sol: dia = 45 cm = 0.45 m

Population = 30000; $Q_{\text{design}} = 3.5 Q_{\text{DWF}}$

$S = ?$

Running full

$n = 0.012$

Factor = 0.80

Rate of water supply = 150 lpcd

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

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

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

$Q_{\text{design}} = 3.5 \times 0.0416$
 $= 0.1456 \text{ m}^3/\text{sec}$

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

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

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

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

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

$S = 0.0022$

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

05. Ans: 1.353 m³/sec

Sol: $Q = ?$

$d = 1.25 \text{ m}$

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

Half-full

$A = \frac{\pi}{8} D^2 \quad R = \frac{D}{4}$

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

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

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

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

Sol: $V_{\text{self}} = ?$

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

$S = 2.65$

$K = 0.1$

$f = 0.03$

$n = 0.013$

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

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

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

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

$0.656 = \frac{1}{0.03} \cdot \left(\frac{1}{4}\right)^{2/3} \cdot (S)^{1/2}$

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

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

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

Sol: dia of sewer $D = ?$

$$n = 0.013$$

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

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

Flow full

$$A = \frac{\pi}{4} D^2$$

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

$$Q = A \cdot V$$

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

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

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

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

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

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

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

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

$$V = 0.88 \times \frac{1}{0.014} \cdot \left(\frac{0.36}{4}\right)^{2/3} \cdot \left(\frac{1}{1000}\right)^{1/2}$$

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

08. Ans: (a)

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

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

dia of sewer = 600 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: $\frac{Q_{\text{full}}}{Q_{\text{half}}} = \frac{A_{\text{full}} V}{A_{\text{half}} V} = \frac{\frac{\pi}{4} D^2 \times v}{\frac{\pi}{8} D^2 \times v} = 2$

The Velocity remains same for the pipe flowing full and half full, if diameter and bed slope remains same.

10. Ans: (c)

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

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

$$n = 0.015 ;$$

$$S = 1/280$$

To find 'Q'

$$\begin{aligned} Q &= A.V = \frac{\pi}{4}.D^2 \times \frac{1}{n}.R^{2/3}.S^{1/2} \\ &= \frac{\pi}{4}.(0.3)^2 \times \frac{1}{0.015} \times \left(\frac{0.3}{4}\right)^{2/3} \times \left(\frac{1}{280}\right)^{1/2} \\ &= 0.05 \text{ m}^3/\text{sec} \\ &= 4320 \text{ m}^3/\text{day} \end{aligned}$$

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

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

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

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

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

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

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

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

11. Ans: (c)

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

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

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

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

$$\begin{aligned} &= \frac{\frac{\sqrt{3}}{4}D}{\frac{D}{2}} \\ &= \frac{\sqrt{3}}{2} \end{aligned}$$

$$\theta = 60^\circ$$

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

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

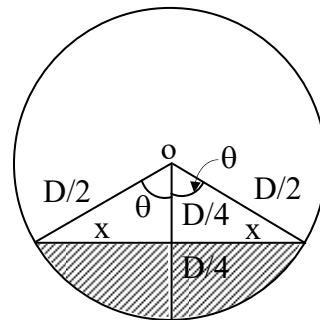
$$120^\circ \rightarrow ?$$

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

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

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

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



03. Characteristics of Sewage

01. Ans: 212.19 mg/lit

Sol: Ultimate BOD $L_0 = ?$

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

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

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

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

$$(D_0)_{\text{Initial}} = \frac{V_D(D_0)_D + V_S(D_0)_S}{V_0 + V_S}$$

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

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

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

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

$$= 151.4 \text{ mg/l}$$

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

$$y_t^{\text{TOC}} = L_0(1 - e^{-K_t t})$$

$$y_t^{20^\circ\text{C}} = 151.4 = L_0(1 - e^{-K_{20} \times 5})$$

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

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

02. Ans: (d)

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

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

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

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

$$(D_0)_I = (D_0)_{\text{mixer}} = \frac{V_0(D_0)_0 + V_S(D_0)_S}{V_0 + V_S}$$

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

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

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

03. Ans: (c)

Sol: Fail in finding the BOD of waste water

04. Ans: 90 mg/l

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

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

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

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

$$K_{20} (\text{base 10}) = 0.1 \text{ d}^{-1} = 2.3 \times 0.1$$

$$= 0.23 \text{ d}^{-1}$$

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

$$y_5^{30} = L_0(1 - e^{-K_{30} \times 5})$$

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

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

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

$$110 = L_0(1 - e^{-0.364 \times 5})$$

$$L_0 = 131.78 \text{ mg/l}$$

$$y_5^{20} = L_0(1 - e^{-K_{20} \times 5})$$

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

05. Ans: 246.36 mg/l

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

$$\begin{aligned} K_{(20)} &= 0.1 \text{d}^{-1} \\ &= 2.3 \times 0.1 \\ &= 0.23 \text{d}^{-1} \end{aligned}$$

$$y_1^{30^{\circ}\text{C}} = L_0(1 - e^{-0.364 \times 1})$$

$$110 = L_0(1 - e^{-364 \times 1})$$

$$L_0 = 360.5 \text{ mg/l}$$

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

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

$$y_5^{20} = L_0(1 - e^{-K_{20} \times 5})$$

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

06. Ans: 304000

Sol: $Q = 80 \times 10^6 \text{ l/d}$, $y_5 = 285 \text{ mg/l}$,

compute daily 5 day O_2 demand

$$\begin{aligned} \text{Total strength of waste} &= Q \times y \\ &= 80 \times 285 \\ &= 22800 \text{ kg/day} \end{aligned}$$

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

$$75 \text{ g} = \frac{22800}{\text{per capita BOD}}$$

$$\text{Per} = \frac{22800}{75 \times 10^{-3}} = \frac{\text{kg/day}}{\text{kg/day}}$$

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

07. Ans: 93.72%

$$\begin{aligned} \text{Sol: } S_r &= 100(1 - 0.794^t) \\ &= 100(1 - 0.794^{12}) \\ S_r &= 93.72\% \end{aligned}$$

08. Ans: 1%

Sol: $\text{BOD}_5 = 600 \text{ mg/l}$,

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

BOD_u remain unoxidised after 20 days =?

$$y_5^{20^{\circ}\text{C}} = L_0(1 - e^{-Kt})$$

$$600 = L_0(1 - e^{-0.23 \times 5})$$

$$L_0 = 878.01 \text{ mg/l}$$

$$L_{20} = L_0 e^{-Kt}$$

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

$$= 878.01 \times e^{-0.23 \times 20} = 8.82 \text{ mg/l}$$

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

1% of BOD after 20 days

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

$$\text{Diluted} = \frac{300}{5} = 60$$

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

$$= [9.2 - 6.9] \times 60 = 138 \text{ mg/l}$$

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

$$\text{BOD}_{\text{avg}} = \frac{138 + 141}{2} = 139.5 \text{ mg/l}$$

10. Ans: (c)

Sol: $K = 0.01 \text{ h}^{-1}$ (base)

$$= 0.01 \times 24 \text{ h}^{-1}$$

$$= 0.24 \text{ h}^{-1}$$

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

$$190 = L_0(1 - e^{-0.0124 \times 5})$$

$$L_0 = \frac{190}{(1 - e^{-0.024 \times 5})} = 271.89 \text{ mg/l}$$

11. Ans: (d)

Sol: $y_5^{20} = 180 \text{ mg/l}$, $K_T = K_{20}(1.047)^{T-20}$

BOD = 2.5 day

$$[y_5^{20} = L_0(1 - e^{-0.18 \times 5})]$$

$$y_{2.5}^{T^0C} = 180 \text{ mg/l}$$

$$y_5^{20} = y_{2.5}^{T^0C}$$

$$L_0(1 - e^{-K_{20} \times 5}) = L_0(1 - e^{-K_T \times 2.5})$$

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

$$(1.047)^{T-20} = \frac{5}{2.5}$$

$$(T-20)\text{Ln}(1.047) = \text{Ln}2$$

$$(T-20)0.045 = 0.693$$

$$T = 35^0C$$

12. Ans: (c)

Sol: $\text{BOD}_3 = 75 \text{ mg/l}$, $K = 0.345 \text{ d}^{-1}$ (base e)

BOD = 10 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)

Sol: $y_5^{20^0C} = 200 \text{ mg/l}$

$$y_5^{30^0C} > y_5^{20^0C}$$

$$\therefore k_{30} > k_{20}$$

15. Ans: (c)

Sol: Ultimate BOD is independent of time and temperature and remain same at all temperature.

16. Ans: (b)

Sol: $y_5^{20^0C} = [(DO)_I - (DO)_F] \times DF$

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

17. Ans: (a)

Sol: Organic matter in waste water is used as food by micro organisms in BOD test.

18. Ans: (c)

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

$$= \frac{\text{total BOD}}{\text{per capita BOD}}$$

$$= \frac{Qy}{80 \times 10^{-3}} = \frac{1 \times 162}{80 \times 10^{-3}} = 2025$$

19. Ans: (b)

Sol: $[(D_0)_i] = 8 \text{ mg/l}$, $(D_0)_f = 2 \text{ mg/l}$

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

$$\begin{aligned} 5 \text{ days BOD} &= [(D_0)_i - (D_0)_f] \times \text{D.F.} \\ &= (8-2) \times 150 \\ &= 900 \text{ mg/l} \end{aligned}$$

20. Ans: (a)

Sol: Ferroin is used as indicator in COD test

21. Ans: (c)

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

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

$$L_0 = \frac{250}{(1 - e^{-K_t \times t})}$$

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

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

$$L_0(1 - e^{-K_{20} \times 5}) = L_0(1 - e^{-K_{30} \times t})$$

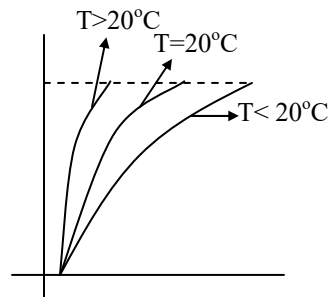
$$K_{20} \times 5 = K_{30} \times t$$

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

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

22. Ans: (a)

Sol:



$T > 20^\circ\text{C}$ curve shift to the left

23. Ans: 128.1 mg/l

Sol: $y_5^{20} = ?$

$$y_7^{20} = 150 \text{ mg/l}$$

$$K = 0.23 \text{ d}^{-1}$$

$$150 = L_0(1 - e^{-0.23 \times 7})$$

$$L_0 = 187.47 \text{ mg/l}$$

$$y_5^{20} = L_0(1 - e^{-0.23 \times 5})$$

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

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

04. Treatment of Sewage
02. Ans: (d)
Sol: $12 \text{ m} \times 1.50$, $H = 0.8 \text{ m}$, $Q = 720 \text{ m}^3/\text{hr}$
 $L = 12 \text{ m}$, $B = 1.50 \text{ m}$

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

$$= \frac{720}{12 \times 1.50} = 40 \text{ m}^3/\text{hr}/\text{m}^2$$

$$= 40000 \text{ lit}/\text{hr}/\text{m}^2$$

$$\begin{aligned} \text{D.T} &= \frac{\text{Volume of G.C}}{Q} = \frac{L \times B \times H}{Q} \\ &= \frac{12 \times 1.5 \times 0.8}{\frac{720}{60}} = 1.2 \text{ min} \end{aligned}$$

04. Ans: (b)
Sol: $Q = 3 \text{ m}^3/\text{sec}$, cross section of grit chamber = ?

 Cross section area (B.H) = $\frac{Q}{V_H}$

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

$$A = \frac{3}{0.3} = 10 \text{ m}^2$$

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

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

$$V_s = \frac{9.81 \times (2.70 - 1) \times (0.21 \times 10^{-3})^2}{18 \times 1 \times 10^{-6}}$$

$$V_s = 0.04089 \text{ m/sec}$$

$$V_s = 4.089 \text{ cm/sec}$$

06. Ans: (b)
Sol: $L = 7.5 \text{ m}$

$$V_H = 0.3 \text{ m/sec}$$

$$H = 0.9 \text{ m}$$

$$\begin{aligned} V &= \frac{\mu}{\rho} = \frac{1.002 \times 10^{-3}}{1000} \\ &= 1.002 \times 10^{-6} \text{ m}^2/\text{sec} \end{aligned}$$

$$\text{For } \eta = 100\%, \frac{L}{V_H} = \frac{H}{V_s}$$

$$\Rightarrow V_s = 0.036 \text{ m/sec}$$

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

$$0.036 = \frac{9.8}{18} (2.5 - 1) \cdot \frac{d^2}{(1.002 \times 10^{-6})}$$

$$d = 0.21 \text{ mm}$$

07. Ans: (a)
Sol: $V_H = 0.25 \text{ m/s}$
 $\text{D.T} = 1 \text{ minute}$

$$L = V_H \times \text{D.T}$$

$$= 0.25 \times 1 \times 60$$

$$= 15 \text{ m}$$

08. Ans: (d)

Sol: $Q = 5005 \text{ m}^3/\text{d}$

$$V_0 = 35 \text{ m}^3/\text{m}^2/\text{d}$$

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

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

$$d = 13.5 \text{ m}$$

05. 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

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

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

$$550 \times 10^{-3} = \frac{50 \times 180}{V}$$

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

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

$$V = 16363 \text{ m}^3$$

02. Ans: (d)

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

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

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

$$0.5 = \frac{50,000 \times 180}{1800 \times V}$$

$$\Rightarrow V = \frac{50000 \times 180}{0.5 \times 1880}$$

$$V = 10,000 \text{ m}^3$$

03. Ans: (a)

Sol: $X = 2000 \text{ mg/l}$

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

$$= \frac{176}{2000} = \frac{176}{2} = 88 \text{ ml/gm}$$

Common Data for Question Nos. 4 to 7

04. Ans: (c)

Sol: $Q = 35,000 \text{ m}^3/\text{d}$, $V = 10900 \text{ m}^3$,

$$y_i = 250 \text{ mg/l}, y_e = 20 \text{ mg/l}$$

$$\text{MLSS} = 2500 \text{ mg/l}$$

$$\text{Aeration period} = \frac{V}{Q} = \frac{10900}{\frac{35000}{24}} = 7.47 \text{ hrs}$$

05. Ans: (b)

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

$$= \frac{35000(250)}{10,900 \times 2500} \frac{\text{m}^3/\text{d}/(\text{mg})/\text{l}}{\text{m}^3/\text{mg/l}}$$

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

06. Ans: (c)

$$\begin{aligned}\text{Sol: } \eta_{\text{BOD}} &= \frac{y_i - y_e}{y_i} \times 100 \\ &= \frac{250 - 20}{250} \times 100 = 92\%\end{aligned}$$

07. Ans: (a)

$$\begin{aligned}\text{Sol: Sludge age } \theta_c &= \frac{VX}{Q_w X_u + Q_e \times X_e} \\ &= \frac{10900 \times 2500}{220 \times 9700 + (35000 - 220)30} \text{ m}^3 \times \frac{\text{mg}}{\text{l}} \\ &= 8.57 \text{ days}\end{aligned}$$

08. Ans: (c)

Sol: $\text{SVI} = 88 \text{ ml/gm}$, $X_u = ?$

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

09. Ans: (d)

Sol: $V = 400 \text{ m}^3$, $X = 1000 \text{ mg/l}$

Total amount of MLSS in aeration

$$\begin{aligned}\text{Tank} &= VX \\ &= \text{m}^3 (\text{mg/l}) \\ &= 400 \times 1000 \times (1000 \times 10^{-6}) \\ &= 400 \text{ kg}\end{aligned}$$

11. Ans: (c)

Sol: $X = 2800 \text{ mg/l}$ carried out 1 lit sample

$$V = 200 \text{ ml}$$

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

Common data for Q 12 & 13

12. Ans: (c)

Sol: Given,

$$Q = 500 \text{ m}^3/\text{h}$$

$$y_i = 150 \text{ mg/l}$$

$$y_e = 10 \text{ mg/l}$$

$$D T = 8 \text{ hours}$$

$$Q_c = 240 \text{ hours}$$

$$V = 4000 \text{ m}^3$$

$$X = 2000 \text{ mg/l}$$

$$\frac{F}{M} = \frac{Q \cdot y_i}{VX} = \frac{500 \times 150}{4000 \times 2000}$$

$$\frac{F}{M} = 9.375 \times 10^{-3} \text{ per hour}$$

$$\frac{F}{M} = 9.377 \times 10^{-3} \times 24 \text{ per day}$$

$$\frac{F}{M} = 0.225 \text{ per days}$$

13. Ans: (c)

$$\text{Sol: } Q_c = \frac{\text{mass of solid reactors}}{\text{mass of solid wasted per day}}$$

$$Q_c = \frac{VX}{\text{mass of solid wasted per day}}$$

$$\text{Mass of solid wasted/day} = \frac{VX}{Q_c}$$

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

$$= 800 \text{ kg/day}$$

14. Ans: (d)

Sol: $X = 4000 \text{ mg/l} = 4 \text{ gm/l}$

Volume = 200 ml

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

$$\text{SVI} = 50 \text{ ml/gm}$$

16. Ans: 7.5 days

Sol: From the data $X = 3000 \text{ mg/lit}$

$$Q_w = 50 \text{ m}^3/\text{day}$$

$$X_u = 1000 \text{ mg/lit}$$

$$Q - Q_w = 14950 \text{ m}^3/\text{day}$$

$$\Rightarrow Q - 50 = 14950 \text{ m}^3/\text{day}$$

$$Q = 15,000 \text{ m}^3/\text{day}$$

$$V = Q \times D.T$$

$$= 15,000 \times 2 \text{ hr}$$

$$= 15,000 \times \frac{2}{24} = 1250 \text{ m}^3$$

$$\theta_c = \frac{VX}{Q_w X_u + (Q - Q_w) X_e}$$

$$\theta_c = \frac{1250 \times 3000}{50 \times 10,000 + (14950) \times 0}$$

$$= 7.5 \text{ days}$$

17. 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:

Flow rate (Q) = 10,000 m³/day

Inflow BOD (y_i) = 150 mg/lit

Outflow BOD (y_E) = 20 mg/lit

MLSS (X) = 3,000 mg/lit

We know

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

$$VX = \frac{10,000 \times 150}{0.25}$$

$$VX = 6 \times 10^6$$

(I) Volume of aeration tank

$$V = \frac{6 \times 10^6}{3 \times 10^3} \quad (\because X = 3000 \text{ mg/lit})$$

$$\therefore \text{Volume} = 2000 \text{ m}^3$$

$$\text{(II) Aeration period} = \frac{2000}{10,000} \times 24 = 4.8 \text{ hours}$$

(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

$$\text{MCRT} = \theta_c = \frac{VX}{Q_w X_u + Q_e X_e}$$

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

∴ Mass of sludge wasted per day = 600 kg/day

(VI) Volume of sludge wasted per day

$Q_w x_u + Q_e x_e = \text{mass of sludge wasted per day}$

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

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

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

$$Q_w = 60 \text{ m}^3/\text{day}$$

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

$$\text{S.V.I} = 100$$

$$\text{(VIII) } \frac{Q_R}{Q} = \text{Recycling ratio} = \frac{X}{X_w - X}$$

$$\Rightarrow \frac{Q_R}{Q} = \frac{3000}{10000 - 3000} = 0.4285$$

(IX) ∴ Rate of return sludge

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

$$Q_R = 4285 \text{ m}^3/\text{day}$$

06. 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: $\text{OLR} = 0.175 \text{ kg/m}^3/\text{day}$

$y_i = 150 \text{ mg/l}$

$y_e = ?$

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

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

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

$$\frac{Q y_i}{V} \text{ kg of BOD/day/ ha.m}$$

$$\text{OLR} = 0.175 \times 10^4 \text{ kg/ha.m/day}$$

$$\eta = \frac{150 - y_e}{150} \times 100$$

$$\frac{150 - y_e}{150} \times 100 = \frac{100}{1 + 0.0044 \sqrt{\frac{0.175 \times 10^4}{1}}}$$

$$y_e = 23.31 \text{ mg/l}$$

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

Sol: Q = 6 MLD

$$y_i = 150 \text{ mg/l}$$

$$\text{OLR} = 175 \text{ gm/m}^3/\text{day}$$

$$\text{Depth of TF} = ?$$

$$\text{Vol. of TF} = ?$$

$$\text{SLR} = 2500 \text{ l/m}^2/\text{day}$$

$$\eta = ?$$

$$y_e = ?$$

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

$$\frac{\pi}{4} \times d^2 = \frac{6 \times 10^6}{2500}$$

$$d = 55.27 \text{ m}$$

$$\text{organic loading length} = \frac{Q \cdot y_i}{V}$$

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

$$V = 5142.85 \text{ m}^3$$

$$\text{Depth of TF} = \frac{\text{Vol. of TF}}{\text{surface area of TF}}$$

$$d = \frac{5142.85}{2400}$$

$$d = 2.14 \text{ m}$$

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

$$\text{OLR} = 1750 \text{ kg/ha. m/day}$$

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

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

$$\eta = 84.45\%$$

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

$$84.45 = \frac{150 - y_e}{150} \times 100$$

$$y_e = 23.32 \text{ mg/l}$$

04. Ans: 633 m³

Sol: Single stage TF; $y_e = 20 \text{ mg/l}$

$$y_i = 120 \text{ mg/l}; \quad Q = 2200 \text{ m}^3/\text{day}$$

$$R = 4000 \text{ m}^3/\text{day}; \quad V = ?$$

∵ Recirculation is there it is high rate TF

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

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

$$F = 2.017$$

$$Q = 2200 \text{ m}^3/\text{day}$$

$$Q = 2200 \times 1000 \text{ lpcd}$$

$$Q = 2.2 \text{ MLD}$$

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

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

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

$$V = 0.0633 \text{ ha. m}$$

$$V = 633 \text{ m}^3$$

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. Sludge Digestion

01. Ans: 17105.62 kg/day, 16.68 m³/day

Sol: $Q = 4.5$ MLD

$$\begin{aligned} \text{Total dry solids} &= Q \times \text{sewage containing} \\ &= 4.5 \times 275 = 1237.5 \text{ kg} \end{aligned}$$

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

Solids concentration in sludge

$$= \frac{55}{100} \times 275$$

$$= 151.25 \text{ mg/l}$$

Total mass of dry solids produced/day

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

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

$$= 17015.625 \text{ kg/day}$$

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

$$1.02 = \frac{\rho_{\text{Sludge}}}{\rho_w}$$

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

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

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

$$\begin{aligned} \text{Volume of sludge} &= \frac{17015.625}{1020} \\ &= 16.68 \text{ m}^3/\text{day} \end{aligned}$$

03. Ans: (c)

$$\text{Sol: } \frac{V_2}{V_1} = \frac{100 - P_1}{100 - P_2}$$

$$= \frac{100 - 99}{100 - 96} = 25\%$$

$$\begin{aligned} \% \text{ of reduction in volume} &= 100 V_1 - 25 V_1 \\ &= 75\% V_1 \end{aligned}$$

05. Ans: (d)

$$\text{Sol: } V_2 = \frac{100 - P_1}{100 - P_2} \times P = \frac{100 - 98}{100 - 96} \times P$$

$$= \frac{1}{2} (P) = \frac{P}{2}$$

07. 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

$$\therefore \frac{100}{S_s} = \frac{2}{S_{\text{solids}}} + \frac{98}{S_{\text{water}}} \Rightarrow \frac{100}{S_s} = \frac{2}{2.4} + \frac{98}{1}$$

$$\Rightarrow S_s = 1.011$$

$$\rho_s = 1011 \text{ kg/m}^3$$

08. Ans: (c)

Sol: $P_1 = 94\%$

Solid content = 16%

$P_2 = 84\%$

Water content = $100 - 16$
 $= 84\%$

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

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

$$= 5.25 \text{ m}^3$$

08. Septic Tanks

01. Ans: 6.12 m × 3.16 m

Sol: Discharge = $150 \times 200 \times 10^{-3} = 30 \text{ m}^3/\text{day}$

Given detention time = 24 hours

$\therefore$ Volume of septic tank (v) = $t \times Q$

$$= \frac{(24)(30)}{24}$$

$$= 30 \text{ m}^3$$

$$\therefore \text{Area of septic tank} = \frac{(30)}{(1.5)} = 20 \text{ m}^2$$

$$\therefore \text{Given } \frac{L}{B} = 2:1$$

$$L \times B = 20$$

$$2B \times B = 20$$

$$B = 3.16 \text{ m}$$

$$\text{and } L = 6.12 \text{ m}$$

02. Ans: 0.6 m

Sol: Volume of sludge produced

$$= 30 \times 10^{-3} \times 200 \times 2$$

$$= 12 \text{ m}^3$$

$\therefore$ depth of sludge zone

$$= \frac{\text{Volume of sludge}}{\text{Area of septic tank}}$$

$$= \frac{12}{20} = 0.6 \text{ m}$$

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

Sol: Given sewage flow = 150 lpcd

$$\text{Sewage discharge} = 150 \times 10^{-3} \times 120 \text{ m}^3/\text{day} \\ = 18 \text{ m}^3/\text{day}$$

$$\text{Detention period} = \frac{V}{Q} = \frac{4 \times 2 \times 1.5}{18 \text{ m}^3/\text{day}} = 16 \text{ hrs}$$

(a) Volume of sludge = $(Q \times \text{detention time})$
 $= 40 \times 10^{-3} \times 120 \times 2$
 $V = 9.6 \text{ m}^3$

(b) Volume of soakpit
 $= \frac{Q}{\text{Percolation capacity}}$
 $= \frac{(150 \times 120)}{(1500)} = 12 \text{ m}^3$

04. **Ans: (d)**

Sol: $V = 7 \text{ m}^3$

No. of users = 5

R.S.P = $70 \text{ lit/capita/year}$

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

Cleaning interval = cleaning period

Volume of sludge zone = $\text{RSP} \times \text{no. of user} \times \text{C.P}$

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

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

09. Oxidation Ponds

01. **Ans: $L = 282.84 \text{ m}$, $B = 70.71 \text{ m}$, $D.T. = 50 \text{ days}$**

Sol: $Q = \text{population} \times \text{per capita, supply} \times \text{Factor}$
 $= 10,000 \times 100 \times 0.8$
 $= \frac{1000000 \times 0.8}{10^6} = 0.80 \text{ MLD}$

$$y = 40 \text{ g/day}$$

$$D.T = ?$$

80% of BOD removal BOD loading rate
 $= 200 \text{ kg} = \text{BOD/hect/d}$

$$\text{Surface area of pond} = \frac{Q \times y_i}{\text{BOD loading rate}} \\ = \frac{0.8 \times 500}{200} = 2 \text{ ha}$$

$$\text{Total BOD} = Q \times y_i \\ = \text{population} \times \text{per capita BOD} \\ = 0.8 \times y_i = 10,000 \times 100 \times 40 \times 10^{-3}$$

$$y_i = 500 \text{ mg/li}$$

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

$$L = 4B$$

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

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

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

$$L = 4 \times 70.71 = 282.84 \text{ m}$$

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

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

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

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

$$0.8 = \frac{500 \cdot y_e}{500} \Rightarrow 400 = 500 - y_e$$

$$y_e = 500 - 400 = 100 \text{ mg/l}$$

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

Sol: P = 10,000 sewage flow = 150 lpcd

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

$$y_i = 300 \text{ mg/l}, y_e = 30 \text{ mg/l},$$

$$\text{OLR} = 300 \text{ kg/ha/d}$$

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

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

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

$$L \times B = 1.5 \times 10^4 \text{ m}^2$$

$$4B \times B = 1.5 \times 10^4$$

$$B = 61.23 \text{ m}$$

$$\therefore L = 4 \times 61.23 = 244.92 \text{ m}$$

$$\text{Vol of oxidation pond} = Q \times \text{DT}$$

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

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

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

04. Ans: (c)

Sol: Q = 10000 × 200, y = 300 mg/l

Organic loading = 310 kg/day/m

Q = 2 MLD

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

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

10. Disposal of Sewage Effluents

01. Ans: (b)

Sol: $y_R = 200 \text{ mg/l}, Q_R = 50 \text{ m}^3/\text{s}$

$y_w = 8 \text{ mg/l}, Q_w = 500 \text{ m}^3/\text{s}$

$$y_{\text{mix}} = \frac{Q_R y_R + Q_w y_w}{Q_R + Q_w}$$

$$= \frac{50 \times 200 + 500 \times 8}{50 + 500}$$

$$y_{\text{mix}} = 25.45 \text{ mg/l}$$

02. Ans: (c)

Sol: Waste water $(\text{DO})_w = 2 \text{ mg/l}$

$Q_w = 1.10 \text{ m}^3/\text{sec}$

$(\text{DO})_R = 8.3 \text{ mg/l}$

$Q_R = 8.70 \text{ m}^3/\text{sec}$

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

$$(\text{DO})_{\text{mix}} = \frac{2 \times 1.10 + 8.3 \times 8.70}{1.10 + 8.70}$$

$$(\text{DO})_{\text{mix}} = 7.6 \text{ mg/l}$$

03. Ans: 13.85 mg/l, 20.27 mg/l, 5.85 mg/l

Sol: $Q_{\text{RW}} = 12000 \text{ m}^3/\text{d}$, temp = 20°C ,

$$y_w = 50 \text{ mg/l}$$

D.O = concentration = 2 mg/l

$$Q_R = 40,000 \text{ m}^3/\text{d}, y_R = 3 \text{ mg/l},$$

D.O = 7 mg/l, temp = 20°C

$K = 0.23$ (to the base in decay curve)

$$y_{\text{mix}} = \frac{Q_R y_R + Q_w y_w}{Q_R + Q_w}$$

$$= \frac{12000 \times 50 + 40,000 \times 3}{12,000 + 40,000} = 13.84 \text{ mg/lit}$$

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

$$= \frac{12,000 \times 2 + 40,000 \times 7}{12,000 + 40,000}$$

$$= 5.85 \text{ mg/l}$$

$$y_{\text{mix}} = L_0(1 - e^{-k \times t})$$

$$13.85 = L_0(1 - e^{-0.23 \times 5}) = \frac{13.85}{(1 - e^{-0.23 \times 5})}$$

$$L_0 = 20.27 \text{ mg/l}$$

04. 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 10 km

$$= \frac{10 \times 1000}{0.28} \times \frac{1}{24 \times 50 \times 60}$$

$$T = 0.413 \text{ days}$$

$$\text{Ultimate BOD at 10 km d/s} = L_t = L_0 e^{-kt}$$

$$k = 0.25 \text{ 1/day}$$

$$L_{0.413} = 17.142 e^{-0.25 \times 0.413} = 15.459$$

$$\approx 15.46 \text{ mg/l}$$

11. Solid Waste Management

01. Ans: 3870

Sol: Total energy as discarded

$$= \frac{\sum P_i E_i}{100} = \frac{P_1 E_1 + P_2 E_2 + \dots + P_n E_n}{100}$$

$$[20 \times 2500 + 10 \times 10000 + 10 \times 8000 +$$

$$= \frac{10 \times 14000 + 40 \times 3500 + 5 \times 14000 + 5 \times 100}{100}$$

$$= 5805 \text{ kJ/kg}$$

Moisture content of MSW

$$= \frac{20 \times 70 + 10 \times 4 + 10 \times 4 + 10 \times 1 + 40 \times 60 + 5 \times 20 \times 2 + 5 \times 2}{100}$$

$$= 40\%$$

Total energy on dry basis

$$= \text{energy as discarded} \times \frac{100}{100 - \%mc}$$

$$= 5805 \times \frac{100}{100 - 40} = 9675 \text{ kJ/kg}$$

$$\text{Difference in energy content} = 9675 - 5805$$

$$= 3870 \text{ kJ/kg}$$

02. Ans: (b)

Sol: $\frac{100}{\rho_{Msw}} = \frac{\%F.w}{\rho_{Fw}} + \frac{\%DA}{\rho_{DA}} + \frac{\%pla}{\rho_p} + \frac{\%WS}{\rho_{WS}}$

$$= \frac{50}{300} + \frac{30}{500} + \frac{10}{65} + \frac{10}{125}$$

$$= \frac{100}{\rho_{Msw}} = 0.46 \Rightarrow \frac{100}{0.46}$$

$$\rho_{Msw} = 217.1 \text{ kg/m}^3$$

04. Ans: (d)

Sol: 50 g of 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

$$= \frac{75}{120} = 0.625 \text{ parts of green house}$$

$$500 \text{ t of Msw release} = 0.625 \times 500$$

$$\text{Total green house} = 321.5 \text{ of green house}$$

Per capita green house gas contribution

$$= \frac{\text{house gas}}{\text{population of community}}$$

$$= \frac{321.5}{10,00,000} \times 1000 \times 1000$$

$$= 321.5 \text{ mg/l}$$

07. Ans: (d)

Sol: Indore method is aerobic method & Bangalore method is anaerobic method of composting.

08. Ans: (c)

Sol: Plastic & rubber waste is disposed by pyrolysis. (burning in the absence of air) to recover by products.

09. Ans: (d)

Sol: $40t + 35t = 75t$

10. Ans: (b)

Sol: Except human excreta all forms of solid waste is treated as refuse.

11. Ans: 1.46 ha

Sol: Population = 65000

$$\text{Rate of solid waste} = 2 \text{ kg/capita/day}$$

$$\text{Solid waste generated} = 65000 \times 2$$

$$= 130000 \text{ kg/day}$$

$$\text{Solid waste generator per annum}$$

$$= 130000 \times 365 = 47450000$$

$$\text{Volume} = \frac{\text{mass}}{\text{density}}$$

$$V = \frac{47450000}{650}$$

$$V = 73000 \text{ m}^3$$

$$\text{Area} = \frac{\text{Volume}}{\text{depth}} = \frac{73000}{5}$$

$$A = 14600 \text{ m}^2 = 1.46 \text{ ha}$$

12. Ans: (a)

$$\text{Sol: } \frac{100}{\rho_{\text{sludge}}} = \frac{c_1}{\rho_1} + \frac{c_2}{\rho_2}$$

$$\Rightarrow \rho_{\text{sludge}} = \frac{100}{\frac{c_1}{\rho_1} + \frac{c_2}{\rho_2}}$$

13. 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

$$S_w = \frac{3.65 \times 10^9}{100} = 36.5 \times 10^6 \text{ m}^3$$

Volume of compacted solid waste

$$= \frac{36.5 \times 10^6}{4} = 9.125 \times 10^6 \text{ m}^3$$

$$\frac{\text{Compacted fill}}{\text{Compacted solid waste}} = 1.5$$

Volume of land fill (compacted fill)

$$= 9.125 \times 10^6 \times 1.5$$

$$= 13.6875 \times 10^6 \text{ million m}^3$$

12. Air Pollution and Control

05. Ans: (d)

$$\text{Sol: } \text{CHCl}_3 = 12 + 1 + 3 \times 35.5$$

$$= 119.5 \text{ gm molecular.}$$

$$\text{Concentration} = 0.4 \mu\text{g} / \text{m}^3$$

@ 273⁰ k

$$T_1 = 273^0 \text{ k} \quad T_2 = 293^0 \text{ k}$$

$$P_1 = 1 \quad P_e = 1$$

$$V_1 = 22.4 \text{ lit/mol} \quad V_2 = ?$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{22.4}{273} = \frac{V_2}{293} \Rightarrow V_2 = 24.04 \text{ lit/mol}$$

$$\mu\text{g} / \text{m}^3 = \frac{\text{PPm} \times \text{gm.mole.} \times 10^3}{\text{lit/mol}}$$

$$0.4 = \frac{\text{PPm} \times 119.5 \times 10^3}{24.04}$$

$$\text{PPM} = 8.047 \times 10^{-5} \times 10^3 [\because 1 \text{ billion} = 10^9]$$

$$= 0.08$$

$$\text{Parts per billion} = 8.047 \times 10^{-5} \times 10^3 = 0.08$$

07. Ans: (a)

$$\text{Sol: Dry air cools at } 9.8^0 \text{ per km}$$

$$\approx 10^0 \text{ km}$$

$$\text{For } \frac{1}{2} \text{ km} \rightarrow 5^0 \text{ fall}$$

$$\text{Final temperature at 500 m elevation}$$

$$= 40^0 - 5^0 = 35^0 \text{ c}$$

08. Ans: (c)

Sol: Initial dry cot = 9.787 g, rate
 $= 1.5 \text{ m}^3/\text{min}$ for 24 m^3
 Final = 10.283 g

$$= \frac{(w_{\text{Initial}} - w_{\text{final}})}{\text{Volume of air sample}} \text{ filter paper}$$

Volume of air sample = rate of rate simplify
 $\times \text{duration}$

$$= 145 \times 24 \times 60 = 2088 \text{ m}^3$$

Total suspended particulate

$$= \frac{(10.283 - 9.787)}{2088}$$

$$= 2.375 \times 10^{-4} \text{ gm/m}^3$$

$$= 2.375 \times 10^{-4} \times 10^6$$

$$= 237.5 \text{ } \mu\text{g/m}^3$$

14. Ans: (c)

Sol: 20000 km, No. = 50,000, rate
 $= 2 \text{ gm/km/vehicle}$

$$= 2 \times 50,000 \times 20000 \times \frac{1}{10^6}$$

$$= 2000 \text{ t}$$

15. Ans: (b)

Sol: A $\rightarrow$ Inversion

B $\rightarrow$ Sub adiabatic

C $\rightarrow$ Dry adiabatic

D $\rightarrow$ Super adiabatic

16. Ans: (a)

Sol: Looping $\rightarrow$ Unstable atmospheric plume
 behaviour conditions

17. Ans: (b)

Sol: during winter nights severe inversion
 occur.

18. Ans: (c)

Sol: (A) Acid rain $\rightarrow \text{SO}_2$

(B) Acute toxicity $\rightarrow \text{CO}$

(C) Ozone liberation $\rightarrow \text{NO}_x$

(D) Green house effect $\rightarrow \text{CO}_2$

19. Ans: (a)

Sol: Lapse rate

$$= \frac{dT}{dt} = \frac{21.25 - 15.70}{444 - 4} = 1.42/100$$

Lapse rate $>$ ALR ($-1^\circ\text{C} / 100 \text{ m}$)

($-1.42 / 100 \text{ m}$)

$\therefore$ it is super adiabatic lapse rate.

20. Ans: (c)

Sol: ESP and fabric filters remove very fine

21. Ans: 0.011268

$$\text{Sol: } \frac{P}{RT} = 41.6 \text{ mol} / \text{m}^3$$

$$\frac{RT}{P} \times 10^3 = \text{constant} = 24.038$$

$$1 \mu\text{g} / \text{m}^3 = \frac{24.038}{M \times 10^3} \text{ ppm}$$

$$30 \mu\text{g}/\text{m}^3 \text{ of } \text{SO}_2 = \frac{24.038}{64 \times 10^3} \times 30$$

$$= 0.011268 \text{ ppm}$$

22. 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 $= \pi dH$

$$= \pi \times 0.45 \times 7.5$$

Number of bags required $= \frac{300}{\pi \times 0.45 \times 7.5}$

$$= 28.29 \approx 29$$

23. 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 $A = 8012.38 \text{ m}^2$

24. Ans: 592.88

Sol: % sulphur in coal = 2

Rate of coal consumption = 30 kg/min

% sulphur in ash = 6

$$\text{SO}_2 \text{ emission} = \left(\frac{\text{t}}{\text{year}} \right) = ?$$

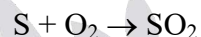
Total sulphur produced = Rate of Coal consumption $\times$ % sulphur in Coal

$$30 \times \frac{2}{100} \text{ kg/min} \times \frac{365 \times 24 \times 60}{1000} \times \text{t/year}$$

(Convert in to tonn/year)

SO_2 emission of gas =

$$30 \times \frac{2}{100} \times \frac{365 \times 24 \times 60}{1000} \left(\frac{100 - 6}{100} \right) = 296.45 \text{ /year}$$



$$\text{S} = 32$$

$$\text{SO}_2 = 64$$

32 Parts of sulphur = 64 parts of SO_2

$$1 \text{ Part of } \text{SO}_2 = \frac{64}{32} \text{ parts of } \text{SO}_2$$

296.4 t/year of sulphur produce

$$= \frac{64}{32} \times 296.4 \text{ t/year of } \text{SO}_2$$

$$\text{SO}_2 \text{ emission} = \frac{64}{32} \times 296.4$$

$$= 529.8$$