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Text Book : Theory with worked out Examples and Practice Questions

8 Environmental Engineering

(Solutions for Text Book Practice Questions)

Water Supply Engineering

01. Population Forecasting & Water Demands

01. Ans: (c)

Sol:

1970	1980	1990	2000
40000	47000	53000	58000

Increments: 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	$\frac{1.4-1}{1}\times100=40$
3	1.68	$\frac{1.68-1.4}{1.4}\times100=20$

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

$$\bar{r} = (40\times20)^{1/2}$$

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

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

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

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

$P_1 = 2.15$ lakh $= 2.20$ 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)

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

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

$$P_{2020} = 50000 + 3\times5000 + \frac{3\times4}{2}\times500$$

$P_{2020} = 68000$

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

$Q_{2020} = P_{2020}$ × per capita water supply

= 743900 × 200 × 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)	$\frac{158500}{400000}\times100 = 39.6\%$
2	558500		
		217500 (dP_2)	$\frac{217500}{558500}\times100 = 38.94\%$
3	776000		
		322500 (dP_3)	$\frac{322500}{776000}\times100 = 41.5\%$
4	1098500		
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,

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

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

6000m^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 = 1.5decades = 15years

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

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

$r_0 = 11.5$

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

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

Conventional Practice Solutions

01.

Sol:

Year	Population	$\overline{x}$	$\overline{r}$
1960	70,000	30000	$\frac{100000 - 70000}{70000} \times 100$ = 42.85
1970	1,00,000	50000	$\frac{150000 - 100000}{100000} \times 100$ = 50
1980	1,50,000	50000	$\frac{200000 - 150000}{150000} \times 100$ = 33.33
1990	2,00,000	40000	$\frac{240000 - 200000}{200000} \times 100$ = 20
2000	2,40,000		

Arithmetical Increase Method

$$\overline{x} = \frac{30,000 + 50,000 + 50,000 + 40,000}{4}$$

$$= \frac{170000}{4}$$

$$\bar{x} = 42500$$

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

$$P_{2020} = 24{,}0000 + 2(42500)$$

$$P_{2020} = 325000$$

Geometrical increase methods:

$$r_1 = \frac{P_2 - P_1}{P_1} \times 100$$

$$r = (r_1 \times r_2 \ldots\ldots r_{n)})^{1/n}$$

$$\bar{r} = (42.85 \times 50 \times 33.33 \times 20)^{1/4}$$

$$= 34.56\%$$

$$P_o = 240000$$

$$n = 2$$

$$P_{2020} = P_2 = P_o\left(1 + \frac{\bar{r}}{100}\right)^2$$

$$= 2{,}40{,}000\left(1 + \frac{34.56}{100}\right)^2$$

$$= 4{,}34{,}554$$

02.

Sol:

Year	Population	Per Decade increase in population $\bar{x}$	Incremental over increasing in population $\bar{y}$
1951	350000		
		116600	
1961	466600		$527400 - 116600 = 410800$
		527400	
1971	994000		$566000 - 527400 = 38600$
		566000	
1981	1560000		$63000 - 566000 = -503000$
		63000	
1991	1623000		

$$\bar{x} = \frac{116600 + 527400 + 566000 + 63000}{4}$$

$$\bar{x} = 318250$$

$$\bar{y} = \frac{410800 + 38600 - 503000}{3} = -\,17866$$

$$P_n = P_o + n\bar{x} + \frac{n(n+1)\bar{y}}{2} = 1623000 + 3(318250) + \frac{3(3+1)}{2}(-17866.67)$$

$$P_{2021} = 2470550$$

02. Sources and Conveyance of Water

01. Ans: (a)

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

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

02. Ans: (b)

Sol: Total area of slots required =

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

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

$= 4\times10^{-6}$ 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)

03. 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 m*l* $\quad (pH)_A = 7$

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

Sample B, V_B = 700 m*l* $\quad (pH)_B = 5$

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

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

$$(H^+)_{mix} = \frac{300\times10^{-7} + 700\times10^{-5}}{300+700}$$

$(H^+)_{mix} = 7.03\times10^{-6}$ mol/lit

$$(pH)_{mix} = \log_{10}\frac{1}{(H^+)_{mix}} = \log_{10}\frac{1}{7.03\times10^{-6}}$$

$(pH)_{mix} = 5.15$

17. Ans: (d)

Sol: CO_3^{--} = 90 mg/*l* $\qquad HCO_3^-$ = 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^- mol/lit = $OH^- \times$ Mol.wt.of $OH^- \times 1000$

$OH^- = 10^{-5}\times17\times1000 = 0.17$ 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: $TH = Ca \times \frac{50}{20} + Mg \times \frac{50}{12.2}$

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

$TH \simeq 179$ mg/l as $CaCO_3$

Common data for Q 29 & 30

29. Ans: (a)

Sol: TH in mg/lit as $CaCO_3$

$= Ca^{++}$ in mg/lit $\times \frac{50}{20} + Mg^{++}$ 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 $CaCO_3$

$= HCO_3^-$ in mg/lit $\times \frac{50}{61} + CO_3^{2-}$ 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: $Alkalinity = 250 \times \frac{50}{61}$

$= 204.9 \approx 205$ 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

$H^+ = \frac{10^{-14}}{10^{-8.6}} = 10^{-5.4}$ 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 $CO_3 = 12 + 3\times16 = 60$

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

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

$$OH^- = \frac{17}{17\times1000} = 10^{-3}\ \text{mol/lit}$$

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

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

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

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

∴ 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

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

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

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

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

Volatile solid

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

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

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

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

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

04. Plain Sedimentation

Common data for Qs. 1, 2 & 3

01. Ans: (b)

Sol: B = 6 m, L = 15 m, H = 3 m

Q = 2 MLD

$$\text{Surface over flow rate } V_0 = \frac{2 \times 10^6}{6 \times 15 \times 24}$$

$$= 926 \text{ lit/hr/m}^2$$

02. Ans: (d)

Sol: Detention time is

Volume of setting tank = Q × D.T

$$DT = \frac{6 \times 15 \times 3}{\frac{2 \times 10^6}{24 \times 10^3}} = \frac{270}{83.33} = 3.24 \text{ hrs}$$

03. Ans: (a)

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

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

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

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

Common data for Qs. 04 & 05

04. Ans: (c)

Sol: Q = 1.8 MLD

D.T = 4 hours

V = ?

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

Volume of tank = Q × DT

$= 75 \times 4 = 300$ m^3

05. Ans: (b)

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

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

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

$L \times B = 150$ m^2

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

$L^2 = 150 \times 4 \Rightarrow L = 24.49$ 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 = 3.33×10^{-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 = ?

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

11. Ans: (d)

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

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

$$= 159\ m^3/day/m$$

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

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

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

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

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

For 100% removal

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

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

L : 3B = 660.011

L × B

3B × B = 660.011

$3B^2 = 660.011$

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

L = 3 × B = 3 × 14.83 = 44.49 m

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

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

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

Sol: L × B × H = 100 × 50 × 3 m,

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

Surface flow rate -- ?, ρ = 2.65 g/cc,

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

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

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

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

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, η = ?

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

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

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

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

$V_0 = 8.99 \times 10^{-5}$ 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: η = 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

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

Overal removal = $\Sigma P_i\eta_i$

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

= 56%

18. Ans: (b)

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

ρ = 1000 kg/m^3

μ = 0.001 N-s/m^2, 1 stoke = 10^{-4}m^2/sec

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

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

$g = 9.8$ m/sec^2

$G = 2.65$

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

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

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

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

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

$$A = \frac{0.01}{3.20\times10^{-3}} = 3.1214\,m^2$$

20. Ans: 22.576

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

$V_o = 40$ m^3/m^2/day $= 40$ m/day

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

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

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

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

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

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

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

$= 22.576$ µm

21. Ans: 112.66

Sol: Surface over flow rate

$V_o = 32.5$ m^3/day/m^2

L = 32.5 m, B = 8.0 m, D = 2.25 m

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

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

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

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

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

$= 112.66$ m^3/day/m

22. Ans: (d)

Sol: $v_s \propto d^2$

If 'd' doubles it increase by 4 times.

∴ 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:

$V_s = 3\ m^3/hour/m^2$

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

26. Ans: (b)

Sol: $V = 2500\ m^3$

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

DT = ?

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

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

27. Ans: (a)

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

$Q = 2400\ m^3/day$

$V_s = ?$

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

For 100%, $V_s = V_o = 24$ m/day

$$\Rightarrow \frac{24}{24}\,m/hr = 1\,m/hr$$

28. Ans: (b)

Sol:

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

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

$= V_o = 1$ m/hour

Concentration of particle removed = 165 mg/*l*

Conventional Practice Solutions

01.

Sol: Given data:

Discharge, Q = 0.5 m^3/sec

Over flow rate, $V_0 = 32.5\ m^3/day/m^2$

$$V_0 = \frac{32.5}{24 \times 60 \times 60} = 3.76 \times 10^{-4}\ m^3/sec/m^2$$

Detention time = 95 mins

$$\frac{L}{B} = \frac{2}{1} \text{ to } \frac{5}{1}$$

$L \not> 100m$

To find surface area of a settling tank

$$\text{Overflow rate, } V_0 = \frac{\text{Discharge}}{\text{surface area}}$$

$$\text{Surface Area} = \frac{\text{Discharge}}{\text{Overflow Rate}}$$

$$= \frac{0.5}{3.76 \times 10^{-4}}$$

$$= 1329.78 m^2$$

Assume the $\frac{L}{B} = \frac{3}{1}$

L = 3B

Area = L × B

1329.78 = 3B × B

B = 21.05m ≃ 22 m

L = 63.15m ≃ 64 m, L ≯ 100m

Hence OK

Dimension of the tank 64m × 22m

To find the depth of the clarifier

Volume of the tank

= Discharge × Detention time

= 0.5 × 95× 60

= 2850 m^3

Volume of clarifier = Area × depth

Area × depth = 2850

Depth = 2.02 ≃ 2.10 m

∴ Dimension of the tank 64 m× 22m×2.10m

02.

Sol: Equation for settling velocity of a spherical particle in liquid

Consider a spherical discrete particle of diameter 'd' settling from water. This particle is subjected to

- Force of gravity [F_g]
- Force of buoyancy [F_b]

$F_g = \gamma_P V_P = \rho_p g V_P$

$F_b = \gamma_w V_P = \rho_w g V_P$

For particle settlement

$F_g \geq F_b$

$\therefore F_{net} = F_g - F_b$

$= \rho_p g V_p - \rho_w g V_P$

$= g v_P [\rho_P - \rho_w]$

Once motion initiates in water a drag force acts on a particle, F_D

Drag force = $C_D A_p \cdot \rho_w \cdot \frac{V^2}{2}$

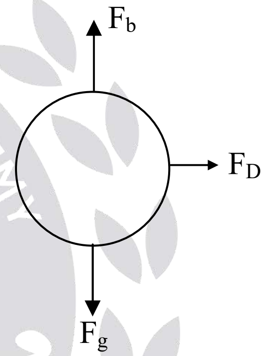
Where C_D = coefficient of drag

A_p = Area of particle

ρ_w = density of water

V = velocity of fall

ρ_p= density of particle



Discrete Particle

$F_{net} \geq F_D$

$\therefore F_{net} = F_D$

$$gV_P[\rho_P - \rho_w] = \frac{C_D A_P \rho_w V^2}{2}$$

$$V^2 = \frac{2g[\rho_P - \rho_w]V_P}{C_D \rho_w A_P} \quad \rightarrow (1)$$

V_P = Volume of spherical particle

A_P = Area of spherical particle

$$\frac{V_P}{A_p} = \frac{\frac{\pi d^3}{6}}{\frac{\pi d^2}{4}} = \frac{2}{3} d$$

Substitute in the equation (1)

$$V^2 = \frac{2g[\rho_P - \rho_w] \times \frac{2}{3} d}{C_D \rho_w}$$

$$V^2 = \frac{\frac{4}{3} g[\rho_p - \rho_w] d}{C_D \rho_w}$$ → Stoke's law of terminal settling velocity.

C_D → coefficient of drag, shows the turbulency of water.

The value of coefficient of drag (C_D) changes and depends upon the flow regimes surrounding the particle.

$$C_D = \frac{24}{R_e}$$ →laminar flow

$$C_D = \frac{24}{R_e} + \frac{3}{\sqrt{R_e}} + 0.34$$ →Transition flow

$C_D = 0.4$ → Turbulent flow

For settling, the particles maintain the flow as laminar flow is classified based on Reynold's number, R_e

$$R_e = \frac{\rho V d}{\mu}$$

$R_e < 1$ → Laminar flow

$R_e = 1 \times 10^4$ → Transition flow

$R_e > 10^4$ → Turbulent flow

Sir George Gabriel stokes, while calculating settling velocity for small spherical particles falling under laminar (quiescent) condition.

$$C_D = \frac{24}{R_e} = \frac{24}{\frac{\rho_w V d}{\mu}} = \frac{24\mu}{\rho_w V d}$$

Substitute in the stoke's law of terminal settling velocity

$$V^2 = \frac{\frac{4}{3} g[\rho_P - \rho_W] d}{\frac{24\mu}{\rho_W V \times d}}$$

$$V^2 = \frac{\frac{4}{3} g[\rho_P - \rho_w] d \times V \times d}{24\mu}$$

$$V = \frac{\frac{4}{3} g[\rho_P - \rho_w] d^2}{24\mu}$$

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

$$\gamma = \frac{\mu}{\rho_w}, \mu = \gamma \rho_w$$

$$V = \frac{g[\rho_P - \rho_w] d^2}{18\mu}$$

$$V = \frac{g\rho_w \left[\frac{\rho_p}{\rho_w} - 1\right] d^2}{18\mu}$$

Specific gravity $s = \frac{\rho_p}{\rho_w}$

$$V = \frac{g[s-1] d^2}{\frac{18\mu}{\rho_w}}$$

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

Where, V = settling velocity

S = specific gravity

d = diameter of particle

γ = kinematic viscosity

05. 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

$$= \frac{1.68\times10\times10^6\times365}{10^6}$$

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

= 6132

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

Sol: Quantity of water to be treated = 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 × 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: 3780 kg

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

Dose of alum = 25 mg/l

Total alum required in kg/day

= Q (MLD) × dose of alum (mg/l)

= 5.04 ×25 = 126 kg/day

Monthly alum requirement = 126 × 30

= 3780 kg

06. Ans: (b)

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

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

$P = (600)^2\times2\times1\times10^{-3} = 720$ 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 × 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, $\mu = 1.0087 \times 10^{-3}$ N-S/m^2

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

$\frac{L}{B} = 2$, 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 × 2B × 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.

Conventional Practice Solutions

01.

Sol: Given data:

L = 20 m; B = 10 m; D = 3.5 m

Q = 25 MLD

Paddles: L = 10 m; B = 0.3 m, n = 4

N = 2 rpm;

r = 1.5 m

Mean velocity = $\frac{1}{4}$th velocity of paddle

Dynamic viscosity , $\mu = 1 \times 10^{-3}$ N-sec/m^2

No. of paddles on each shaft = 2

$$P = \frac{C_D A_p \rho_w V_r^3}{2}$$

A_p = No. of shafts × No. of paddles × area of each paddles

$= 4 \times 2 \times 10 \times 0.3 = 24\ m^2$

$$\omega = \frac{2\pi N}{60} = \frac{2\pi\times2}{60} = 0.209$$

$V_p = \omega \times r$

$= 0.209 \times 1.5 = 0.314$ m/sec

$V_r = V_p - V_w$

$V_w = V_p - V_r$

$V_w = 1/4\ V_p$

$1/4\ V_p = V_p - V_r$

$V_r = V_p - 1/4\ V_p$

$$= 3/4\ V_p = \frac{3}{4}\times0.314$$

$V_r = 0.235$ m/sec

(i) Power: $P = \dfrac{1.9\times24\times1000\times(0.235)^3}{2}$

= 295.89 watts

(ii) Time of flocculation:

$$\text{Detention time} = \frac{\text{Volume of flocculation}}{\text{discharge}}$$

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

$$= \frac{20\times10\times3.5}{\frac{25\times10^6}{10^3\times24\times60}} = \frac{700}{17.36}$$

$= 40.32$ min

(iii) Velocity Gradient:

$$G = \sqrt{\frac{P}{V\mu}} = \sqrt{\frac{295.89}{(20\times10\times3.5)\times1\times10^{-3}}}$$

$G = 20.56\ \text{sec}^{-1}$

06. 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 $Q_{density} = 1.8 \times Q$

= 1.8 × 7500000

= 135 × 10^5 lit/day

ROF = 180 lit/hr/m^2

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

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

No. of filters in operations = 5

(1 act as stand by)

Area of each filter L × B

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

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

L : B = 2 : 1 ⇒ L = 2B

2B × B = 625 m^2

B^2 = 625/2

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

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

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

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

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

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

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

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

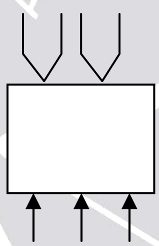
Sol: $Q = 0.25\ m^3$/sec, No. of filters = 4,

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

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

L : B = 2 : 1

L = ?, B = ?



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

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

$= 180\ m^2$

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

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

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

04. Ans: 0.27 m

Sol: V_s = 3m/hr

L = 0.6m $\phi = 0.8$

d = 0.5 mm   e = 0.4

S = 2.65 $\nu = 1\times10^{-6} m^2/sec$

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

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

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

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

$= 271.75$

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

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

$= 0.27$ m

05. Ans: 0.032 m/sec, 0.6258 m

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

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

$$= \frac{9.81(2.66-1)\times(0.65\times10^{-3})^2}{18\times1.3\times10^{-2}\times10^{-4}}$$

= 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 = ?

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

$$46.06 = \frac{1}{Z_2}\times4.606$$

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

$Z_2 = 0.10$ 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

$$\text{Total area} = \frac{Q}{ROF} = \frac{0.5}{\frac{200}{24\times60\times60}}$$

= 216 m^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

$$\text{Loading rate} = \frac{Q}{\text{surface area}} = \frac{86400}{12\times50}$$

= 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

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

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

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

17. **Refer to GATE – Previous Questions Book Page No. 776 Q.No. 07**

18. **Refer to GATE – Previous Questions Book Page No. 777 Q.No. 09**

Conventional Practice Solutions

01.

Sol: Given data:

Population, P = 3 lakhs

Water demand = 200 litres/capita/day

Rate of filtration, V_o = 5 m^3/m^2/hour

Back wash = 5% filtered water

Back washing period = 30 min

N= Number of Filters =?

L:B = 2: 1

n = 0.50, S = 2.5, d = 0.6 mm

C_D = 5.02

Flow = transition flow

Q = Population × Per capita water/demand

= 3,00,000 × 200

= 60 × 10^6 *l*it/day

= 60 MLD

Rapid sand filters are designed for 2 times the average daily water demand and 5% of filtered water for storage to meet the back wash requirements

$$Q_{max} = 2Q + \frac{5}{100} \times Q$$

$$= 2 \times 60 + \frac{5}{100} \times 60$$

= 123 MLD

Total area of rapid sand filter required $= \frac{Q_{max}}{ROF}$

$$= \frac{123 \times 10^6}{5 \times 24 \times 10^3} = 1025\ m^2$$

Approximate number of filter's required

$N = 1.22\sqrt{Q}$

$N = 1.22\sqrt{123} = 13.53 \approx 14$

$N = 14$

Provide 14 number of rapid sand filters.

Area of each filter

$= \frac{\text{Total area of RSF required}}{\text{number of filters}}$

$L \times B = \frac{1025}{14} = 73.21\ m^3$

$\frac{L}{B} = \frac{2}{1}$

$L = 2B$

$2B \times B = 73.21$

$B = 6.05$ m

$L = 2 \times 6.05 = 12.1$ m

Provided '15' number of rapid sand filters each of size 12.1 m × 6.05 m out of which one filter act as a standby

Up flow velocity, $V_B = V_s (n_e)^{4.5}$

$\frac{Ze}{Z} = \frac{1-n}{1-n_e}$

$\frac{0.66}{0.6} = \frac{1-0.5}{1-n_e}$

$n_e = 0.545$

$V_s^2 = \frac{\frac{4}{3}g(\rho_p - \rho_w)d}{C_D\,\rho_w}$

$= \frac{\frac{4}{3}\times 9.81(2.5\times1000-1000)(0.6\times10^{-3})}{(5.02\times1000)}$

$V_s = 0.048$ m/sec

$V_B = V_s(n_e)^{4.5} = 0.048 \times (0.545)^{4.5}$

$V_B = 3.126 \times 10^{-3}$ m/sec

Headloss, $H_b = Z(1-n)(S-1)$

$= 0.6\,(1-0.5)\,(2.5-1)$

$H_b = 0.45$ m

07. Disinfection

01. Ans: (c)

Sol: Population = 20,000

per capita demand = 150 lit/day

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

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

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

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

Total bleaching powder required/day

$= 3 \times 0.66$

= 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

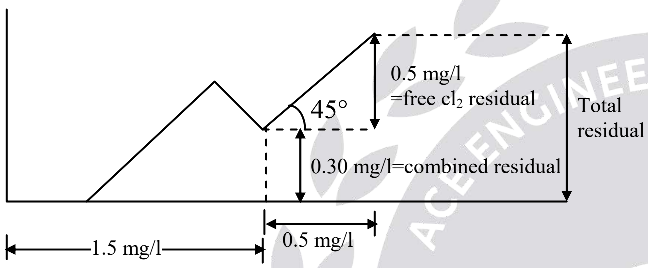
Dose of $Cl_2 = \frac{8}{20} = 0.4$ mg/l

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

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

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

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

pH ≈ 6.568

08. Ans: 3.2 min

Sol: Residual = 0.6 mg/l,

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

t = ?

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

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

$99.7 = \left(1 - e^{-3\times10^{-2}\,t}\right) \times 100$

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

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

09. Ans: 0.56 mg/lit

Sol: pH = 7 → Cl_2 required = 0.7 mg/l

pH = 8 → $K = 2.7 \times 10^{-8}$ what dosage of Cl_2?

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

% of HOCL at given pH,

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

$$\frac{1}{1+\frac{2.7\times10^{-8}}{1\times10^{-7}}} \times 100 = 78.74\%$$

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

$$\%\ HOCL = \frac{1}{1+\frac{2.7\times10^{-8}}{10^{-8}}} \times 100 = 27.02\%$$

For a given degree of kill (% kill)

Cl_2 dose at any pH= Cl_2 dose at given pH × $\frac{\%\,HOCL\text{ at given pH}}{\%\,HOCL\text{ at any pH}}$

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

If pH is 6 then what amount of Cl_2

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

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

$$= 97.37\%$$

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

11. Ans: (c)

Sol: Percentage removal $(\%R)$

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

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

12. Ans: (a)

Sol: Free residual

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

$$2(\text{mg/lit}) = Cl_2\left(\frac{\text{moles}}{\text{lit}}\right)\times\text{Mol.wt}\times1000$$

$$\frac{2}{2\times35.5\times1000} = Cl_2 \ (\text{moles/lit})$$

$$= 2.816\times10^{-5} \ (\text{moles/lit})$$

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

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

$$\frac{HOCL}{OCL^-} = [K][H^+] = 10^{7.5}\times10^{-7.5}$$

$$\therefore HOCL = OCL^-$$

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

$$= 2.816\times10^{-5}(\text{moles/lit})$$

$$\because 2\,OCL^- = 2.816\times10^{-5}$$

$$\because OCL^- = 1.408\times10^{-5}\ \text{moles/lit}$$

13. Ans: (a)

Sol: Dose of bleaching powder = 2 mg/*l*

$$Q = \frac{10000\times50}{10^6} = 0.5\ \text{MLD}$$

Total amount required = Q× Dose of bleaching powder

= 0.5 ×2 = 1 kg/day

14. Ans: (b)

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

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

k = 2.5 $\times10^{-8}$ mol/lit

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

15. Ans: (a)

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

C $\rightarrow$ Concentration of disinfectant

t $\rightarrow$ detention time (or) contact time

n $\rightarrow$ dilution factor.

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

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

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

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

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

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

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

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

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

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

$\therefore$ Total chlorine required for 22 MLD

$= Q_2 \times C_2$

$= 22 \times 2.75 = 60.5$ kg/day

16. Ans: 50.02 m³

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

$K = 0.145$

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

$t = 26.979$ min

Volume of disinfection unit $= Q \times Dt$

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

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/ml

Cl_2 dose = 0.1 mg/l

Volume of water to be treated = 200 ml

Total amount of Bleaching powder required = ?

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

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

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 $NHCl_2$

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

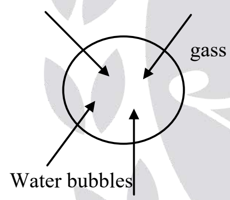
$$= \frac{21.48}{35.5} \times 100$$

= 60%

08. Miscellaneous Water Treatment

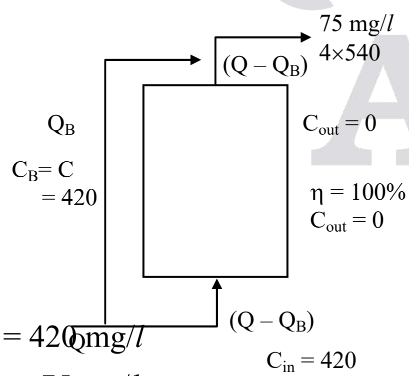
07. Ans: (b)

Sol: liquid-gas system absorption.



10. Ans: 385.714

Sol:



C_{in} = 420 mg/l

C_{out} = 75 mg/l

Q = 4 × 540 = 2160 lit/day

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

= 82.142%

η = 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

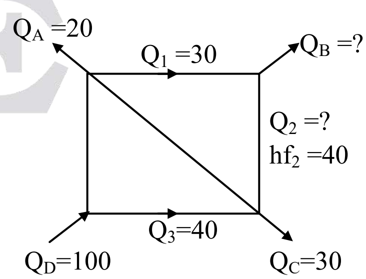
13. Refer to ESE – Volume II(Objective) Book

09. Distribution System

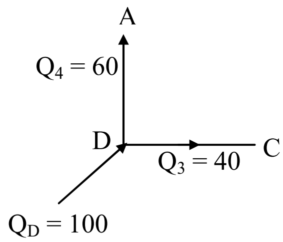
03. Ans:

Sol: Q_B = 50; Q_2 = 20; Q_4 = 60

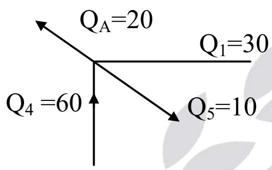
Q_5 = 10; h_{f5} = 20; h_{f4} = 100



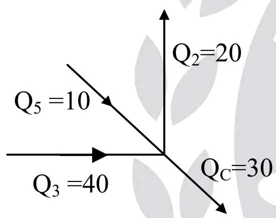
Consider junction 'D', unknown is Q_4



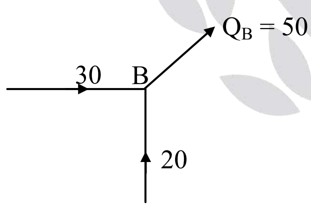
Consider junction A, unknown is Q_5



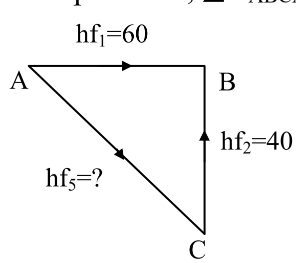
Consider junction C, unknown is Q_2



Consider junction B, unknown is Q_B



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

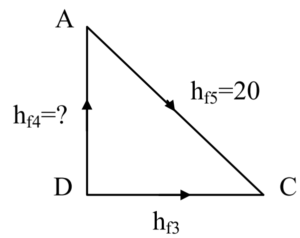


$+h_{f1} - h_{f2} - h_{f5} = 0$

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

$h_{f5} = 20$

Consider loop ACDA



$\Sigma H_{ACDA} = 0$

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

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

$h_{f4} = 100$

06. 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)

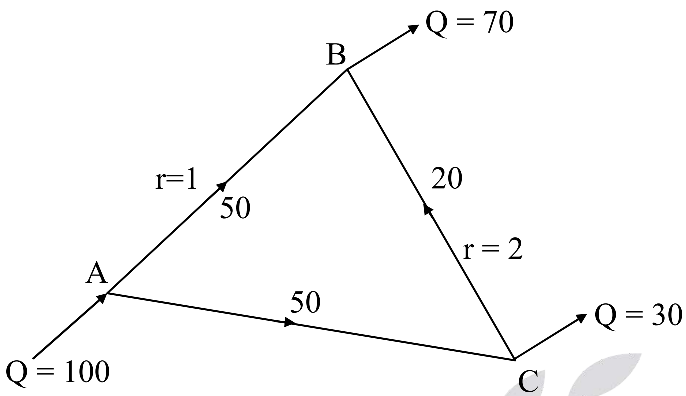
Sol: Water demand at 9^{th} hour = 6.1 ML/hour

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



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

$\Sigma H_{ABCA} = 0$

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

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

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

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

$r_{AC} = 0.615$

Conventional Practice Solutions

01.

Sol: Q = Population × *l*pcd

= 1(270)

= 270 MLD

Volume of water to be supplied = 270 ML

Continuous supply

No. of hours of supply = 24 hrs

Rate of supply

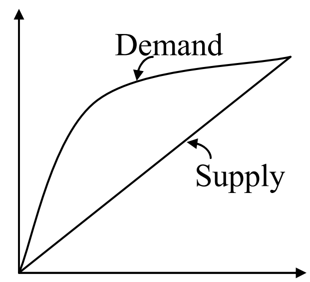
$= \frac{\text{Volume of water to be supplied}}{\text{No. of hours of supply}}$

$= \frac{270}{24} = 11.25$ ML/ hr

Time	Demand (*l*pcd)	Total demand = Population per capita demand (ML)	Total Supply (ML)	Cummulative demand	Cummulative supply	Excess of Demand (ML)	Excess of supply (ML)
5 am to 11 am (6 hrs)	90	90	6 × 11.25 = 67.5	90	67.5	22.5	-
11 am to 3 pm	54	54	4× 11.25 = 45	144	112.5	31.5	-
3 pm to 9 pm	81	81	67.5	225	180	**45**	-
9 pm to 12 mid night	27	27	33.75	252	213.75	38.25	-
12 mid night to 5 am	18	18	56.25	270	270	-	-

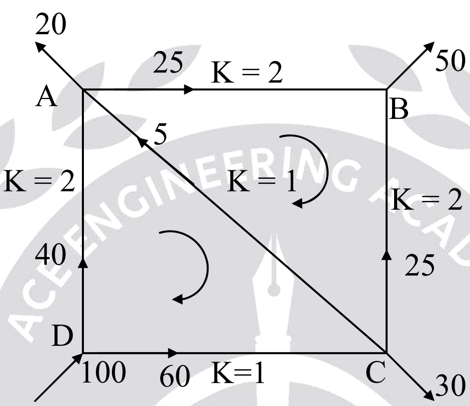
Capacity of reservoir = A + B = 45 + 0

= 45 ML



02.

Sol:



1st Iteration

For loop (ABCA)

Pipe	K	Assumed flow (Q)	$H = KQ^x$	$\left\|\frac{H}{Q}\right\|$	Corrected flow Q' $Q' = Q \pm \delta$
AB	2	+25	1250	50	24.88
BC	2	– 25	–1250	50	–25.12
CA	1	5	25	5	3.4145
			$\Sigma H = 25$	$\Sigma\left\|\frac{H}{Q}\right\| = 105$	

$$\delta_1 = \frac{-\Sigma H}{x\Sigma\left|\frac{H}{Q}\right|} = \frac{-(25)}{2\times 105} = -0.12$$

For loop ACDA

Pipe	K	Assumed flow (Q)	$H = kQ^x$	$\left\|\frac{H}{Q}\right\|$	Corrected flow $Q \pm \delta_2$
AC	1	– 5	–25	5	–3.4145
CD	1	–60	–3600	60	–58.5345
DA	2	40	3200	80	41.4655
			$\Sigma H = -425$	$\Sigma\left\|\frac{H}{Q}\right\| = 145$	

$$\delta_2 = \frac{-(-425)}{2\times 145} = 1.465$$

$Q'_{CA} = Q_{CA} + (\pm\,\delta_1) - (\pm\,\delta_2)$

$= 5 - 0.12 - 1.4655$

$= 3.4145$

$Q'_{AC} = Q_{AC} + (\pm\,\delta_2) - (\pm\,\delta_1)$

$= -5 + 1.4655 + 0.12$

$= -3.4145$

2nd iteration

Loop (ABCA)

Pipe	K	Q''	$H = KQ^2$	$\left\|\frac{H}{Q}\right\|$	$Q'' = Q' \pm \delta'_1$
AB	2	24.88	1238.02	49.76	2.494
BC	2	–25.12	–1262	50.24	–25.06
CA	1	3.4145	11.6588	3.4145	3.4745
			$\Sigma H = -12.3212$	$\Sigma\left\|\frac{H}{Q}\right\| = 103.4145$	

$$\delta'_1 = \frac{-(\Sigma H)}{x\Sigma\left|\frac{H}{Q}\right|} = \frac{-(-12.3212)}{2\times 103.4145} = 0.06$$

Loop ACDA

Pipe	K	Q″	$H = KQ^2$	$\left\lvert\frac{H}{Q}\right\rvert$	$Q'' = Q' \pm \delta_2''$
AC	1	–3.4145	–11.6588	3.4145	–3.4745
CD	1	–58.5345	–3426.2876	58.5345	–58.5345
DA	2	41.4645	3438.609	82.929	41.4645
			ΣH = 0.6626	Σ(H/Q) = 144.878	

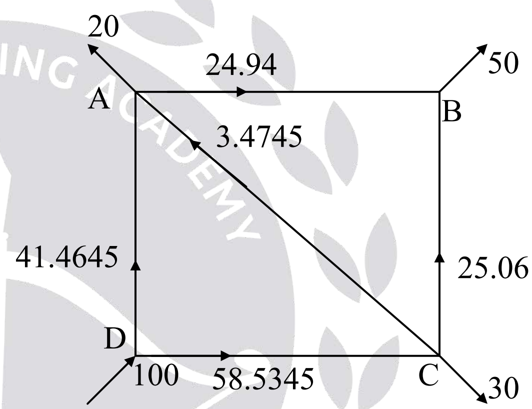
$$\delta_2'' = \frac{-(\Sigma H)}{x\Sigma\left\lvert\frac{H}{Q}\right\rvert} = \frac{0.6626}{2\times 144.878} \simeq 0$$

$Q''_{CA} = Q'_{CA} + (\pm\delta'_1) - (\pm\,\delta'_2)$

$= 3.4145 + 0.06 - 0 = 3.4745$

$Q''_{AC} = Q'_{AC} + (\pm\delta'_2) - (\pm\,\delta'_1)$

$= -\,3.4145 - 0.06 = -\,3.4745$



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:

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

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

$$I = \frac{0.4\times0.8+0.3\times0.2+0.3\times0.1}{1}$$

$= 0.41$

$$Q = \frac{AIR}{360} = \frac{16\times0.41\times50}{360}$$

$= 0.91$ cumecs

03. Ans: 0.1736 m³/sec, 2.015 m³/sec

Sol: Population = 1,00,000

Q_{DWF} = Population × percapita × factor

= 1,00,000 × 200 × 0.75

= 15 × 10^6 lpcd = 15 MLD

= 0.1736 m^3/sec

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

$$R = \frac{25.4a}{t_c + b} = \frac{25.4\times40}{50+20}$$

= 14.51 mm/hr

$$Q_{WWF} = \frac{100\times0.5\times14.51}{360}$$

= 2.015 m^3/sec

04. Ans: 2.508 m³/sec

Sol: P = 40000; A = 75 ha

I = 0.70; Factor = 0.70

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

Q_{DWF} = 40000×120×0.70

= 0.0388 m^3/sec

$$R = \frac{25.4\times40}{40+20} = 16.93 \text{ mm/hr}$$

$$Q_{WWF} = \frac{AIR}{360} = \frac{75\times0.70\times16.93}{360}$$

Q_{WWF} = 2.47 m^3/sec

Combined discharge = 0.0388 + 2.470

= 2.5088 m^3/sec

05. Ans: 0.323 m³/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

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

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

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

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

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

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

$= 0.185 + 0.138$

$= 0.323\ m^3/sec$

06. Ans: 1.61 m^3/sec

Sol: Given Area (A) = 50 ha

Impervious factor (I) = 0.8

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

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

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

t = 50 min

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

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

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

Q = 1.612 m^3/sec

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

02. 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

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

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

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

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

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

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

$S = 1$ in $2159 \simeq 1$ in 2160

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

Sol: Dia of sewer D = ?

n = 0.013

$Q = 0.05\ m^3/sec$

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: For pipe running full,

$$A_{full} = \frac{\pi}{4}D^2,\ R_{full} = \frac{D}{4}$$

For pipe running half full

$$A_{half} = \frac{\pi}{8}D^2,\ R_{half} = \frac{D}{4}$$

$$\therefore \frac{Q_{full}}{Q_{half}} = \frac{A_{full} \times \frac{1}{n}(R_{full})^{2/3}S^{1/2}}{A_{half} \times \frac{1}{n}(R_{half})^{2/3}S^{1/2}}$$

$$= \frac{A_{full} \times (R_{full})^{2/3}}{A_{half} \times (R_{half})^{2/3}}$$

$$= \frac{\frac{\pi}{4}D^2 \times \left(\frac{D}{4}\right)^{2/3}}{\frac{\pi}{8}D^2 \times \left(\frac{D}{4}\right)^{2/3}} = 2$$

10. 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 = ?

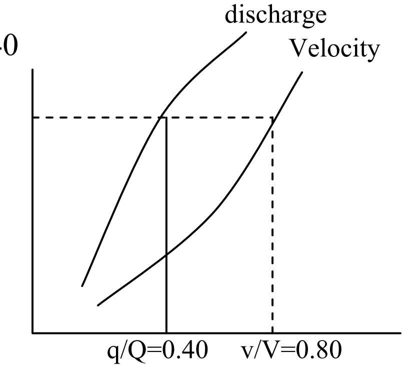
Q = A. V → flow full

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

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

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

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

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

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

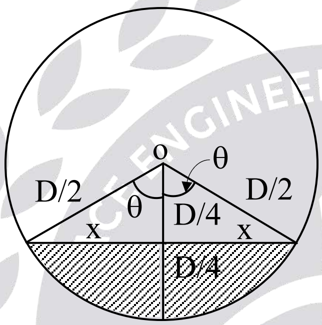
14. **Refer to ESE – Volume II(Objective) Book**

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

03. 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

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

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

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

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

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

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

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

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

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

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

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

05. Ans: 246.36 mg/*l*

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

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

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

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

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

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

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

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

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

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); $K = 0.23d^{-1}$, $L_0 = ?$

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

$L_{20} = L_oe^{-Kt}$

$= 878.01 \times e^{Kt}$

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

$= 8.82$ mg/l

% of unoxidised = $\frac{8.82}{878.01}\times100 = 1\%$

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

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

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

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

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

11. Ans: (d)

Sol: $y_5^{20°C} = 180$ mg/l $\qquad k_{20} = 0.18\ d^{-1}$

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

= 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 = $0.345d^{-1}$ (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: $y_5^{20^\circ C} = [(DO)_I - (DO)_F] \times DF$

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

18. Ans: (c)

Sol: y = 162 mg/*l*

Q = 1000 m^3/day

Q = 1000 × 1000 *l*pcd = 1 MLD

Per capita BOD = 80 gm/capita

Population equivalent

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

$$= \frac{Q\,y}{\text{Per capita BOD}} = \frac{1\times162}{80\times10^{-3}} = 2025$$

19. Ans: (b)

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

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

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

$= (8-2) \times 150$

$= 900$ 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*

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

$$L_o\left(1 - e^{K_{20}\times5}\right) = L_o\left(1 - e^{-K_{30}\times t}\right)$$

$K_{20}\times5 = K_{30}\times t$

$K_{20}\times5 = K_{20}(1.047)^{30-20}\times t$

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

23. Ans: (a)

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

$$L_\circ\left(1 - e^{-K_{20}\times5}\right) = L_\circ\left(1 - e^{-K_{27}\times3}\right) = L_\circ\left(1 - e^{-K_{30}\times4}\right)$$

$$K_{20}\times5 = K_{20}\times(1.047)^{27-20}\times3 = K_{20}(1.047)^{30-20}\times4$$

$5 \simeq 4.13 \simeq 6.33$

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

25. Ans: 128.1 mg/*l*

Sol: $y_5^{20°} = ?$

$y_7^{20°C} = 150\,mg/\ell$

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

$150 = L_o(1 - e^{-0.23\times7})$

$L_o = 187.47$ mg/*l*

$y_5^{20°C} = 187.47(1 - e^{-0.23\times5})$

$y_5^{20°} = 128.11\,mg/\ell$

26. Ans: (c)

Sol: $L_o = 20$ mg/*l*

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

$$\%\text{ BOD exerted in 7days} = \frac{y_7}{L_o}\times100$$

$$= \frac{L_o\left[1 - e^{-Kt}\right]}{L_o}\times100$$

$$= \frac{20\left[1 - e^{-0.15\times7}\right]}{20}\times100$$

$= 65\%$

$$\%\text{ BOD remaining after 7days} = \frac{L_7}{L_o}\times100$$

$$= \frac{L_o e^{-kt}}{L_o}\times100$$

$$= \frac{20\times e^{-0.15\times7}}{20}\times100$$

$= 35\%$

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

04. 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

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

$$= \frac{720}{12\times1.50} = 40\ m^3/hr/m^2$$

$= 40{,}000$ lit/hr/m^2

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

$$= \frac{12\times1.5\times0.8\times60}{720} = 1.2\text{ min}$$

04. Ans: (b)

Sol: Q=3 m^3/sec, cross section of grit chamber =?

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

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

05. Ans: (b)

Sol: G = 2.70

d = 0.21 mm

V_s = ?

$\upsilon = 1\times10^{-2}$ cm²/sec $= 1\times10^{-6}$ m²/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

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

$= 1.002\times10^{-6}$ m²/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 m³/d

V_0 = 35 m³/m²/d

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

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

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

05. 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 × 10⁶ *l*/d = 50 MLD, V = ?

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

$$550\times10^{-3} = \frac{50\times180}{V}$$

$550\times10^{-3}\times V = 9000$

V = 16363 m³

02. Ans: (d)

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

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

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

$$0.5 = \frac{50{,}000 \times 180}{1800 \times V} \Rightarrow V = 10{,}000 m^3$$

03. Ans: (a)

Sol: X = 2000 mg/l

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

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

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

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

05. Ans: (b)

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

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

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

06. Ans: (c)

Sol: $\eta_{BOD} = \frac{y_i - y_e}{y_i} \times 100$

$$= \frac{250 - 20}{250} \times 100 = 92\%$$

07. Ans: (a)

Sol: Sludge age $\theta_c = \frac{VX}{Q_w X_U + Q_e X_e}$

$$= \frac{10900 \times 2500}{220 \times 9700 + (35000 - 220)30}$$

= 8.57 days

08. Ans: (c)

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

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

09. Ans: (c)

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

$$SVI = \frac{V}{X} = \frac{200}{1} = 200\ ml/gm$$

10. Ans: (d)

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

Total amount of MLSS in aeration tank = VX

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

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

$Q = 0.0796\ m^3/s = 6877.44\ m^3/day$

$y_1 = 130$ mg/l,

X = 2100 mg/l

MLVSS = 1500 mg/l,

Volume occupied = 230 ml/lit

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

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

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

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

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

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

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

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 $\quad$ $y_i = 150$ mg/l

$y_e = 10$ mg/l $\quad$ D T = 8 hours

$Q_C = 240$ hours $\quad$ 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: $$Q_C = \frac{\text{mass of solid reactors}}{\text{mass of solid wasted per day}}$$

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

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

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

= 800 kg/day

16. Ans: (d)

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

Volume = 200 ml

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

SVI = 50 ml/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

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

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

(I) Volume of aeration tank

$$V = \frac{6\times10^6}{3\times10^3} \quad (\because X = 3000 \text{ mg}/l\text{it})$$

$\therefore$ Volume = 2000 m^3

(II) Aeration period = $\frac{2000}{10,000}\times 24$
= 4.8 hours

(III) B.O.D removal efficiency

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

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

η = 86.66%

(IV) Volumetric loading rate

$$V_L = \frac{Qy_i}{V} = \frac{10,000\times150}{2000}\times\frac{1000}{10^6}$$

= 0.75 kg/day/m^3

(V) Mass of sludge wasted per day

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

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

$\therefore$ 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

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

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

Q_w = 60 m^3/day

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

S.V.I = 100

(VIII) $\frac{Q_R}{Q}$ = 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

06. 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, 5142.85m^3, 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 = ?

$\eta = ?$

$y_e = ?$

(a) Surface loading rate $= \dfrac{Q}{\text{surface area}}$

$$\frac{\pi}{4}\times d^2 = \frac{6\times10^6}{2500}$$

$d = 55.27$ m

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

$$V = \frac{150\times6}{175\times10^{-3}}$$

$V = 5142.85\ m^3$

$$\text{Depth of TF} = \frac{\text{Vol. of TF}}{\text{surface area of TF}}$$

$$D = \frac{5142.85}{2400} = 2.14\ m$$

(b) OLR = $175\times10^{-3}\times10^4$ kg/ha. m/day

OLR = 1750 kg/ha. m/day

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

$$\eta = \frac{100}{1+0.0044\sqrt{175\times10^{-3}\times10^4}}$$

$\eta = 84.45\%$

(c) $$\eta = \frac{y_i - y_e}{y_i}\times100$$

$$84.45 = \frac{150-y_e}{150}\times100$$

$y_e = 23.32$ mg/l

04. Ans: 633 m^3

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

$$\eta = \frac{y_i - y_e}{y_i}\times100$$

$$\eta = \frac{120-20}{120}\times100 = 83.33\%$$

$$83.33 = \frac{100}{1+0.0044\sqrt{\frac{2.2\times120}{V\times2.017}}}$$

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

Conventional Practice Solutions

01.

Sol: Given data:

Q = 5 MLD y_i = 180 mg/*l*it

y_e = 20 mg/*l*it

$Q_{max} = 2Q = 2 \times 5 = 10$ MLD

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

$$\eta = \frac{180-20}{180} \times 100 = 88.88\%$$

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

For standard rate trickling filter,

recirculation factor, F = 1

$$88.88 = \frac{100}{1+0.0044\sqrt{\frac{10\times180}{V\times1}}}$$

V = 2.23 ha-m

$V = 2.23 \times 10^4\ m^3$

Depth of T.F = 0.9 m to 2.5 m (H = 1.8 m)

Assume depth = H = 1.8 m

$$\text{Surface area of T.F} = \frac{\text{Volume}}{\text{Depth}}$$

$$\frac{\pi}{4} d_s^2 = \frac{2.23 \times 10^4}{1.8}$$

d_s = 125.6 m

Design of high rate trickling filter (HRTF)

$$\frac{R}{I} = 1.5$$

$$F = \frac{1+\frac{R}{I}}{\left(1+0.1\frac{R}{I}\right)^2} = \frac{1+1.5}{(1+0.1\times1.5)^2} = 1.89$$

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

$$88.88 = \frac{100}{1+0.0044\sqrt{\frac{10\times180}{V\times1.89}}}$$

$V = 1.178$ ha-m $= 1.178 \times 10^4\ m^3$

$$\text{Surface area of T.F} = \frac{\text{Volume}}{\text{detph}}$$

$$\frac{\pi}{4} d_H^2 = \frac{1.178\times10^4}{1.8}$$

d_H = 91.28 m

$$\%\text{change in dia} = \frac{d_s - d_H}{d_s} \times 100$$

$$= \frac{125.6 - 91.28}{125.6} \times 100$$

= 27.32 %

02.

Sol: Diameter, d = 25 m

Depth, H = 1.8 m

HLR = 2000 m^3/day

y_e =?

y_i = 150 mg/*l*

K = 2 d^{-1}, n = 0.67

Ecken felder equation

$$y_e = y_i e^{\frac{-kH}{(HLR)^n}}$$

$$y_e = 150 \times e^{\frac{-2(1.8)}{(2000)^{0.67}}}$$

y_e = 146.7 mg/*l*it

07. 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 × 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

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

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

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%

Common Data for Question Nos. 07 & 08

07. Ans: (c)

Sol: Solid content = 2%

∴ water content = 98%

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

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

$S_{sludge} = 1.011$

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

08. Ans: (b)

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

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

$P_2 = 96\%$

$(\because \text{Solid content is } 4\%)$

09. Ans: (d)

Sol: $V_2 = \frac{100-P_1}{100-P_2}\times P = \frac{100-98}{100-96}\times P$

$= \frac{1}{2}(P) = \frac{P}{2}$

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

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

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

$$\Rightarrow S_s = 1.011$$

$$\rho_s = 1011 \text{ kg/m}^3$$

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

15. Ans: (c)

Sol: $P_1 = 94\%$ Solid content = 16%

$P_2 = 84\%$ Water content = 100 – 16

= 84%

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

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

$$= 5.25 \text{ m}^3$$

Conventional Practice Solutions

01.

Sol: Given data:

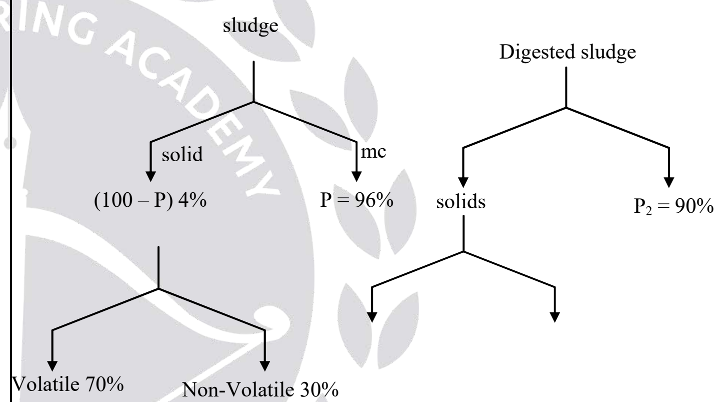
Q = 10 MLD

Solids = 200 mg/l

Volatile = 70%, $S_{vol} = 2.0$

Non volatile = 30%, $S_{non\ vol} = 2.7$

70% of solids settled as a sludge in a sedimentation tank



$P_{raw\ sludge} = 96\%$

After digestion, $P_{digestion} = 90\%$

Capacity of sludge digester:

Reduced digestion = 90%

Digestion period = 50 days

Capacity of digester = ?

Concentration of dry solids in sludge

$= \eta_{st} \times C_{in}$

$$= \frac{70}{100} \times 200 = 140 \text{ mg}/l$$

Total mass of dry solids in raw sludge

M = Q × concentration of dry solids

= 10 × 140 = 1400 kg/day

$$\frac{100}{S_{solid}} = \frac{\%vol}{S_{vol}} + \frac{\%Non\,vol}{S_{non-vol}}$$

$$= \frac{70}{2} + \frac{30}{2.7}$$

$$\frac{100}{S_{solids}} = 35 + 11.11$$

$S_{solids} = 2.17$

$$\frac{100}{S_{sludge}} = \frac{\%solids}{S_{solids}} + \frac{\%m.c}{S_w}$$

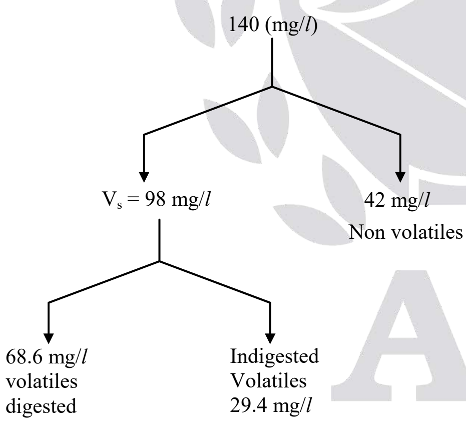
$$\frac{100}{S_{sludge}} = \frac{4}{2.17} + \frac{96}{1}$$

$$\frac{100}{S_{sludge}} = 97.87$$

$S_{sludge} = 1.022$

$\rho_{sludge} = S_{sludge} \times \rho_w$

$= 1.022 \times 1000 = 1022$



$$V_f = \frac{100}{100-96} \times \frac{M_1}{(\rho_{sludge})}$$

$$V_f = \frac{100}{100-96} \times \frac{1400}{1022}$$

$= 34.24\ m^3/day$

Concentration of dry solids in digested sludge = volatiles non remained

$C_2 = 29.4 + 42 = 71.4\ mg/l$

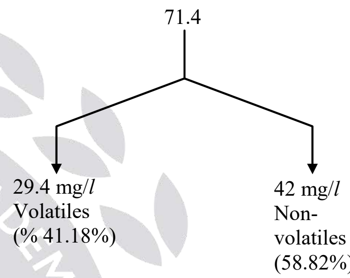
$M_2 = Q \times C_2$

$= 10 \times 71.4 = 714\ kg/day$

$M_2 = 714\ kg/day$

% volatiles in digested sludge = 41.18%

% Nonvolatiles in digested sludge = 58.82%



$$\frac{100}{S_{solid}} = \frac{\%vol}{S_{volatile}} + \frac{\%non\ volatile}{S_{non\ volatile}}$$

$$\frac{100}{S_{solids}} = \frac{41.18}{2} + \frac{58.82}{2.7}$$

$S_{solids} = 2.36$

$$\frac{100}{(S_2)} = \frac{\%Solids}{S_{Solids}} + \frac{\%m.c}{S_w}$$

$$= \frac{10}{2.36} + \frac{90}{1}$$

$S_2 = 1.061$

$(\rho_{sludge})_2 = 1061\ kg/m^2$

$$V_d = \frac{100}{(100-P_2)} \times \frac{M_2}{(\rho_{sludge})_2}$$

$$= \frac{100}{(100-90)} \times \frac{714}{1061}$$

$V_d = 6.729\ m^3/day$

Non-linear digestion:

Capacity of sludge digester (V)

$$= \left(V_f - \frac{2}{3}(V_f - V_d) \right) \times t$$

t = 50 days

$$V = \left(34.24 - \frac{2}{3}(34.24 - 6.728) \right) \times 50$$

$$V = 794.93 \text{ m}^3$$

08. 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 × 150 = 30 m^3/d

Volume = Q × DT

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

L × B × H = 2B × B × 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 × 200 × 10^{-3}

= 6 m^3/year

Volume = 6 × 2 = 12 m^3

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

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 × 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 × 40 = 4.8 m^3/year

Volume of sludge = 4.8 × 2 = 9.6 m^3

(b) Percolation capacity of pit

= 1500 lit/m^3/day

Volume of soak pit =?

Volume of soak

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

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

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

Conventional Practice Solutions

01.

Sol: **Given data:**

Number of users = 200

Settling zone of septic tank:

Volume of settling zone = Q × D.T

Assume Detention Time = 24 hrs

Assume percapita water supply

= 135 *l*pcd (for domestic)

Q_{avg} = Population × Percaptia water supply × 0.8

= 200 × 135 × 0.8

= 21600 *l*it/day

= $2.5 \times 10^{-4}\ m^3/sec$

$Q_{max} = 2 \times Q_{avg}$

= $5 \times 10^{-4}\ m^3/s$

Volume of settling zone

= Q × D.T

= $5 \times 10^{-4} \times 24 \times 60 \times 60$

= $43.2\ m^3$

Sludge zone of septic tank:

Volume of sludge zone = RSP × No. of users × Cleaning period

Volume of sludge zone = 30 × 200 × 2

= 12, 000 lit

= 12×10^3 *l*it

= $12\ m^3$

Total volume of septic tank = Volume of settling zone + Volume of sludge zone

= 43.2 + 12

= $55.2\ m^3$

Assume depth of septic tank = 2 m

(Liquid depth + depth of sludge zone)

Surface area of septic tank, L × B = $\frac{\text{Volume}}{\text{Depth}}$

$= \frac{55.2}{2}$

= $27.6\ m^2$

Assume L:B = 2 : 1

L = 2 B

$2B^2 = 27.6$

B = 3.71 m

L = 7.43 m

Provide a free board of 0.5 m

Overall depth of septic tank = 2 + 0.5 m

= 2.5 m

Provide dimension of septic tank

= 7.43 × 3.71 × 2.5 m

09. Oxidation Ponds

01. Ans: L = 282.84m, B = 70.71m,

DT = 50 days

Sol: Q = population × per capita supply×Factor

= 10,000× 100×0.8

$= \frac{1000000 \times 0.8}{10^6} = 0.80\text{MLD}$

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 × y_i = 10,000 × 100 × 40 × 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 ha = 2 × 10^4 m^2

L = 4B

L × B = 2 × 10^4

4B × B = 2 × 10^4

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

L = 4 × 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 ⇒ 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 = 0.23d^{-1}, L:B = 4:1

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

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

L×B = 1.5×10^4 m^2

4B× B = 1.5×10^4

B = 61.23 m

∴ L = 4 ×61.23 = 244.92 m

Vol of oxidation pond = Q ×DT

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

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

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

05. Ans: (c)

Sol: $Q = 10000 \times 200 = 2$ MLD, $y = 300$ mg/l

Organic loading rate = 310 kg/day/ha

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

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

Conventional Practice Solutions

01.

Sol: Given data:

Population = 10000

Percapita sewage flow = 150 *l*pcd

Discharge, $Q = 150 \times 10000$

$Q = 1.5$ MLD

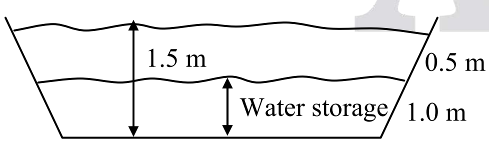
Maximum discharge, $Q_{max} = 2 \times 1.5$

$= 3$ MLD

$y_i = 180$ mg/*l*

OLR = 200 kg/ha/day

Efficiency, $\eta = 80\%$



Surface area of oxidation pond $= \dfrac{Q\ y_i}{OLR}$

$$(L \times B) = \frac{3 \times (180)}{200}$$

$(L \times B) = 2.7$ ha

$(L \times B) = 2.7 \times 10^4$

$L \times B = 27000 \text{ m}^2$

Assume L: B = 4 : 1

$L = 4B$

$$4\ B^2 = 27000\ B = \sqrt{\frac{27000}{4}}$$

$= 82.15$ m

$L = 328.63$ m

Depth = 1.5 m

Volume of oxidation pond = Q × D.T

$L \times B \times H = 3 \text{ MLD} \times D.T$

$82.15 \times 328.63 \times 1.5$

$= 3 \times 10^6 \times 10^{-3} \times DT$

$DT = 13.5$ days

Loss of waste water applied to the pond due to evaporation seepage

$$= \frac{3}{1000} \times \left(2.7 \times 10^4\right) \text{ (m/day) (m}^2\text{)}$$

$= 81 \text{ m}^3$ /day

Net water stored in pond = waste water applied to pond – loss of waste water

$$= \frac{3 \times 10^6}{10^3} - 81 \text{m}^3/\text{day}$$

$= 2919 \text{ m}^3$/day

No. of days of winter storage available in the pond $= \dfrac{\text{Volume of winter storage}}{\text{Net waste water}}$

(Depth of water storage available in pond $= 1.5 - 0.5 = 1$ m)

$$= \frac{2.7 \times 10^4 \times 1}{2919} \text{m}^3/\text{m}^3/\text{day}$$

$= 9.25$ days

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

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

$$(DO)_{mix} = \frac{2\times1.10 + 8.3\times8.70}{1.10+8.70}$$

$(DO)_{mix} = 7.6$ 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 mg/l

$y_{mix} = L_o(1-e^{-k\times t})$

$$13.85 = L_o(1-e^{-0.23\times5}) = \frac{13.85}{(1-e^{-0.23\times5})}$$

$L_o = 20.27$ mg/l

06. Ans: 100 ha

Sol: Q = 8 MLD,

Land capable of consuming

= 80000 lit/ha/day

$$\text{Area of land} = \frac{Q}{\text{consuming capacity of soil}}$$

$$= \frac{8\times10^6}{80000} = 100 \text{ ha}$$

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

$$1.4x = 140$$

$$x = 100$$

Consuming capacity of soil= $\dfrac{Q}{\text{area of land}}$

$$= \frac{4.5\times10^6}{100}$$

= 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
$Q_R = 12\ m^3/sec$	$Q_w = 2m^3/sec$
$(L_0)_R = 5\ mg/l$	$(L_0)_w = 90\ mg/l$

$$(L_o)_{mix} = \frac{Q_R(L_0)_R + Q_W(L_0)_W}{Q_R + Q_w}$$

$$= \frac{12\times5+2\times90}{12+2} = 17.142\ mg/l$$

$Q_{mix} = Q_R + Q_w = 12+2 = 14\ m^3/sec$

$$\text{Velocity} = \frac{Q_{min}}{c/s\,\text{area}} = \frac{14}{50} = 0.28\,m/sec$$

Time taken by the river to travel 10km

$$= \frac{10\times1000}{0.28}\times\frac{1}{24\times60\times60}$$

T = 0.413 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

Conventional Practice Solutions

01.

Sol:

River	Waste water
$Q_R = 0.80\ m^3/s$	$Q_W = 0.2\ m^3/s$
$y_R = 4\ mg/l$	$y_w = 18\ mg/l$
$(DO)_R = (D.O)_{sat} = 9.1\ mg/l$	$(DO)_W = 4\ mg/l$

V = 0.15 m/s

$D_{25\ km} = ?$

$D_{50\ km} = ?$

$K_1 = 0.27\ d^{-1}$(base e)

$K_2 = 0.7\ d^{-1}$ (base e)

$$(D.O)_{mix} = \frac{Q_R(D.O)_R + Q_W(D.O)_W}{Q_R + Q_W}$$

$$= \frac{0.8\times9.1+0.2\times4}{0.8+0.2}$$

= 8.08 mg/l

$D_o = (D.O)_{sat} - (D.O)_{mix}$

Initial oxygen deficit = 9.1 – 8.08 = 1.02 mg/l

$$y_{mix} = \frac{Q_R y_R + Q_W y_W}{Q_R + Q_W}$$

$$= \frac{0.8\times4+0.2\times18}{0.8+0.2}$$

= 6.8 mg/l

Time taken by the river water to travel 25 km on d/s

$$= \frac{distance}{V} = \frac{25\times1000}{0.15}\times\frac{1}{24\times60\times60}$$

= 1.93 days

$$D_t = \frac{K_1L_o}{K_2-K_1}\left[e^{-k_1\times t} - e^{-k_2\times t}\right] + D_o\, e^{-k_2\times t}$$

$L_o = ?$

$y_{mix} = L_o\left[1-e^{-k_1\times5}\right]$

$6.8 = L_o\,[1 - e^{-(0.27\times5)}]$

$L_o = 9.18$ (mg/l)

$D_{1.93}$ days

$$= \frac{K_1L_o}{K_2-K_1}\left[e^{-k_1\times1.93} - e^{-k_2\times1.93}\right] + e^{-k_2\times1.93}(1.02)$$

$$= \frac{(0.27)(9.18)}{0.7-0.27}\left[e^{-(0.27\times1.93)} - e^{-(0.7\times1.93)}\right] + e^{-(0.7\times1.93)}\times1.02$$

$D_{1.93\ day} = D_{25\ km} = 2.19$ (mg/l)

(DO) at 25 km

$= (DO)_{saturation}$ – oxygen deficiency

= 9.1 – 2.19

= 6.91 mg/$l$it

Time taken by the river water to travel 50 km distance $= \dfrac{distance}{V}$

$$= \frac{50\times1000}{0.15\times24\times60\times60} = 3.86 \text{ days}$$

$$D_{3.86}\text{ day} = D_{50} = \frac{K_1L_o}{K_2-K_1}\left[e^{-k_1\times t} - e^{-k_2\times t}\right] + D_o\, e^{-k_2\times t}$$

$$= \frac{(0.27)(9.18)}{(0.7)-0.27}\left[e^{-0.27\times3.86} - e^{-0.7\times3.86}\right] + (1.02)e^{-0.7\times3.86}$$

1.715 mg/l

(DO)50 km = (DO_{sat}) – Deficiency at 50 kN

= 9.1 – 1.715

= 7.385

$$t_c = \frac{1}{k_2-k_1}\ell n\left[\frac{k_2}{k_1}\left(1-1.02\frac{0.7-0.27}{0.27\times9.18}\right)\right]$$

$$= \frac{1}{0.7-0.27}\ell n\left[\frac{0.7}{0.27}\left(1-1.02\times\frac{(0.7-0.27)}{0.27\times 9.18}\right)\right]$$

= 1.76 days

$$D_c = \frac{K_1}{K_2} L_o e^{-K_1\times t_c}$$

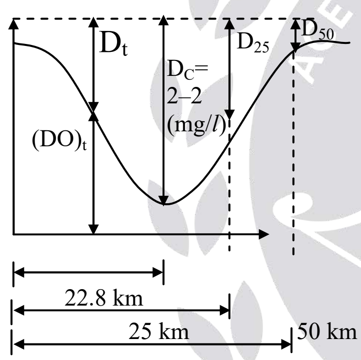
$$= \frac{0.27}{0.7}(9.18)e^{-0.27\times 1.76}$$

= 2.2 mg/l

Distance at which critical deficit occurs = $t_c \times V$

= 1.76 × 24 × 60 × 60 × 0.15

= 22.8 km



11. Solid Waste Management

01. Ans: 14740 kJ/kg, 18658.2 kJ/kg, 19918.9 kJ/kg

Sol:

(i) Total energy content as discarded= $\sum \frac{P_i E_i}{100}$

$$= \frac{15\times 4650 + 45\times 16750 + 10\times 16300 + 10\times 32600 + 10\times 6500 + 5\times 18600 + 5\times 700}{100}$$

= 14740 kJ/kg

(ii) Energy on dry basis = Energy as discarded $\times \frac{100}{100 - \%m.c}$

$$= 14740 \times \frac{100}{100-21} = 18658.22 \text{ kJ/kg}$$

(iii) Energy content on an ash – free dry basis

$$= \frac{100}{100 - \%m.c - \%ash}$$

$$= \frac{100}{100-21-5}\times 14740 = 19918.9 \text{ kJ/kg}$$

02. Ans: (b)

Sol: $\frac{100}{\rho_{Msw}} = \frac{\%F.W}{\rho_{Fw}} + \frac{\%DA}{\rho_{DA}} + \frac{\%pla}{\rho_p} + \frac{\%w\ \&\ y}{\rho_{w\&y}}$

$$= \frac{50}{300} + \frac{30}{500} + \frac{10}{65} + \frac{10}{125}$$

$$= \frac{100}{\rho_{Msw}} = 0.46 \Rightarrow \frac{100}{0.46}$$

$\rho_{Msw} = 217.1$ 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: $\frac{100}{\rho_{sludge}} = \frac{c_1}{\rho_1} + \frac{c_2}{\rho_2} \Rightarrow \rho_{sludge} = \frac{100}{\frac{c_1}{\rho_1} + \frac{c_2}{\rho_2}}$

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

$$S_w = \frac{3.65 \times 10^9}{100} = 36.5 \times 10^6\ m^3$$

$$\text{Volume of compacted solid waste} = \frac{36.5 \times 10^6}{4}$$

$= 9.125 \times 10^6\ m^3$

$$\frac{\text{Compacted fill}}{\text{Compacted solid waste}} = 1.5$$

Volume of land fill (compacted fill)

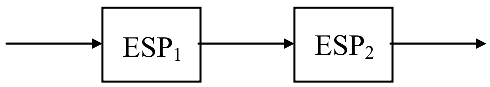
$= 9.125 \times 10^6 \times 1.5$

$= 13.6875 \times 10^6$ million m^3

12. Air Pollution and Control

05. Ans: (b)

Sol:



$\eta_1 = 80$ $\eta_2 = 65\%$

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: $CHCl_3 = 12 + 1 + 3 \times 35.5$

$= 119.5$ gm molecular.

Concentration $= 0.4\ \mu g/m^3 @ 273^0$ k

$T_1 = 273^0$ k $\quad T_2 = 293^0$k

$P_1 = 1 \quad P_2 = 1$

$V_1 = 22.4$ lit/ mol $\quad V_2 = ?$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{22.4}{273} = \frac{V_2}{293} \Rightarrow V_2 = 24.04\,\text{lit/mol}$$

$$\mu g/m^3 = \frac{PPM \times gm.mole. \times 10^3}{lit/mol}$$

$$0.4 = \frac{PPM \times 119.5 \times 10^3}{24.04 \times 10^{-3}}$$

$PPM = 8.047 \times 10^{-5} \times 10^3$

$[\because 1\text{billion} = 10^9] = 0.08$

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

$$= \frac{1.5 + 1.4}{2} \times (24 \times 60) = 2088\,m^3$$

$$TSP = \frac{\text{final weight of filter paper} - \text{Initial weight of filter paper}}{\text{Volume of air sampled}}$$

$$= \frac{10.283 - 9.787}{2088} = 2.375 \times 10^{-4}\ gm/m^3$$

$= 2.375 \times 10^{-4} \times 10^6 = 237.547\ \mu g/m^3$

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: $\frac{P}{RT} = 41.6\, mo\ell/m^3$

$\frac{RT}{P} \times 10^3$ = constant = 24.038

$$1\mu g/m^3 = \frac{24.038}{M \times 10^3} \text{ ppm}$$

30 μg/m³ of SO_2 $= \frac{24.038}{64 \times 10^3} \times 30$

= 0.011268 ppm

24. Ans: (b)

Sol: $v = \frac{2}{60} m/sec$

Total surface area of bags required $= \frac{Q}{v}$

$$\frac{10}{2/60} = 300 \text{ m}^2$$

Surface area of each bag = πdH

= π× 0.45 × 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 η = 96% A = 5600 m²

η = 97% A = 6100 m²

η = 99% A = ?

$0.96 = 1 - e^{\frac{-5600 \times w}{185}}$ ⇒ W = 0.1063 m/sec

$0.99 = 1 - e^{\frac{-A \times 0.1063}{185}}$ ⇒ A = 8012.38 m²

plate area of collector A = 8012.38 m²

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

$$30\times\frac{2}{100}\text{kg/min}\times\frac{365\times24\times60}{1000}\times\text{t/year}$$

(Convert in to tonn/year)

SO_2 emission of gas

$$= 30\times\frac{2}{100}\times\frac{365\times24\times60}{1000}\left(\frac{100-6}{100}\right)$$

= 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

13. Noise Pollution

01. Ans: (b)

Sol: $L_1 = 60\text{ dB} = 20\log_{10}\frac{P_1}{P_0} = 20\log_{10}\frac{P_1}{20}$

$P_1 = P_2$

$P_{rms} = \sqrt{(20000)^2 + (20000)^2} = 28284.27$ dB

Total SPL $= 20\log_{10}\frac{P_{rms}}{P_0}$

$= 20\log_{10}\frac{28284.27}{20}$

= 63 dB (or)

(or) 60 + 3 = 63 dB

02. Ans: (b)

Sol: L_1 = 80 dB, L_2 = 60 dB

80 + 0 = 80 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 dB

04. 87.3 dB

Sol:

$$\ell_{eq} = 10\log_{10}\Sigma\left(10^{\frac{\ell_i}{10}}\times T_i\right)$$

$$T_i = \frac{t_i}{T}$$

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 dB

05. Ans: (c)

Sol: P = 2000 μ bar

Particular = 10^5 N/m^{2}cPa)

1 μ bar $10^{-6} \times 10^5$ N/m^2 = 0.1 Pa

$\Rightarrow 10^{-6} \times 10^5 \times 10^6 = 10^5$ μPa

1 μ bar = 10^6 MPa

$1 = 20 \log_{10} \frac{2000 \times 10^5}{20}$

= 140 dB

08. Ans: (a)

Sol:

$20\log_{10} \frac{P}{P_{ref}} = L$

P = 0.0002 μ

$L = 20\log_{10} \frac{0.0002 \times 10^5}{20} = 0$ 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

$L_2 = L_1 - 20\log_{10}\left(\frac{r_2}{r_1}\right)$

$L_2 = 80 - 20\log_{10}\left(\frac{40}{20}\right)$

$L_2 = 73.98 \text{ dB} \simeq 74\text{dB}$