ACE

GATE | PSUs

CIVIL ENGINEERING

Environmental Engineering

Text Book : Theory with worked out Examples and Practice Questions

Environmental Engineering

(Solutions for Text Book Practice Questions)

Water Supply Engineering

01. Population Forecasting & Water Demands

01. Ans: (c)

Sol:

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

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

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

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

$n = 1$

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

$P_{2010} = 64000$

02. Ans: (c)

Sol:

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

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

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

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

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

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

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

$P_1 = 2.15$ lakh ≃ 2.20 lakh

03. Ans: 1.37 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

Alternative Method

$$P_{2020} = P_{2000}\left[1+\frac{r}{100}\right]^n$$

$$= 1\left[1+\frac{1.6}{100}\right]^{20}$$

$= 1.373$

≃ 1.37 billions

04. Ans: 68000

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

$\bar{y} = 500$ per decade

$P_{2020} = ?$

$P_{1990} = 50000$ (given)

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

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

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

$P_{2020} = 68000$

05. Ans: 743900

Sol:

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

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

$\bar{x} = 111300$

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

$\bar{y} = -57966.67$

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

$P_{2020} = ?$

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

$$P_{2020} = 695200 + 2\times111300 + \frac{2(2+1)}{2}(-57966.67)$$

$P_{2020} = 743900$

06. Ans: 1540000

Sol:

Time	Population	Per decade increased in Population	Per decade % increase 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

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

$= 40\%$

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

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

$= 1537900$

$\simeq 1540000$ [to the nearest 5000]

07. Ans: (c)

Sol: $P_0 = 28{,}000$

Average increase per decade,

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

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

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

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

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

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

$n = 1.5$ decades $= 15$ years

08. Ans: 100765

Sol:

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

Per decade percentage increase in population

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

$r_0 = 11.5$

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

P_o = latest known population

P_n = prospective population after n year

r_o = latest per decade percentage increase in population

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

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

$\overline{D} = 1.635$

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

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

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

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

$= 100765.29 \simeq 100765$

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

09. Ans: (c)

Sol: $P = 1102500$

$r = 5\%$

$n = 2$ years

the population of city '2' years ago is given

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

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

$P_o = 1000000$

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}

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

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

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

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

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

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

$P\overline{H} = 7.47$

15. Ans: (c)

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

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

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

16. Ans: (a)

Sol: Sample A, $V_A = 300$ ml

$(pH)_A = 7$

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

Sample B,

$V_B = 700$ ml

$(pH)_B = 5$

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

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

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

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

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

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

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

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 ml

19. **Ans: (a)**

Sol: PH = 9

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

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

OH^- mg/lit

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

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

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

27. **Ans: (d)**

Sol: TA = 250 mg/l as $CaCO_3$

TH= 350 mg/l as $CaCO_3$

TH > TA

CH = TA = 250 mg/l

NCH = TH – CH = 350 –250

NCH = 100 mg/l as $CaCO_3$

28. **Ans: (c)**

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

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

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

Common data for Q 29 & 30

29. **Ans: (a)**

Sol: TH in mg/lit as C_aCO_3

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

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

= 1500 mg/lit as $CaCO_3$

Shortcut Method

Concentration are already given in Meq/lit

$\therefore$ add $Ca^{+2} + Mg^{+2}$

= (12 + 18) × 50

= 1500 mg/l as $CaCO_3$

30. Ans: (c)

Sol: Alkalinity in mg/lit $CaCO_3$

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

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

= 1750 mg/lit as $CaCO_3$

Shortcut Method

Concentration are already given in Meq/lit

$\therefore$ add Co_3^- + Ho_3^-

= (5 + 35) × 50

= 1750 mg/l as $CACO_3$

Common data for Question Nos. 31. & 32

31. Ans: (c)

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

= 275 mg/lit as $CaCo_3$

32. Ans: (a)

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

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

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

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

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

pH = 5.4

36. Ans: (d)

Sol: From table 10–1–0.10 (MPN) against

2–1–0 + ve group

MPN = 7

For 1–0.1 –0.01 dilution against

2–1–0, +ve group

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

MPN = 7 ×10 = 70

37. Ans: (b)

Sol: $Ca + Co_3 \rightarrow CaCo_3$

Mol. Wt of CO_3 = 12 + 3×16 = 60

Mol. Wt. of Ca = 40

60 parts of CO_3 required = 40 parts of Ca

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

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

= 60 mg/l of Ca

38. Ans: (c)

Sol: PH = 9.25

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

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

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

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

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

$$OH^-(\text{mg}/\ell) = OH^-(\text{mg}/1) \times \text{Mol. Wt . of}$$

$OH^- \times 1000$

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

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

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

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

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

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

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

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+} * 50 + Mg^{2+} * 50

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

= 4×50+1×50 = 250 mg/l as $CaCO_3$

TA = CO_3 * 50 + HCO_3 *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

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

$$TS = \frac{98.484 - 98.42}{100} \times 10^6 = 640\ mg/l$$

(ii) Volatile solids $= \frac{W_2 - W_3}{V}$

$$= \frac{98.484 - 98.462}{100} \times 10^6 = 220\ \text{mg}/l$$

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

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

= 420 mg/l

45. Refer Previous GATE solutions Book

46. Refer Previous GATE solutions Book

04. Plain Sedimentation

Common data for Qs. 1& 2

01. Ans: (b)

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

Q = 2 MLD

$$SOR = \frac{Q}{LB}$$

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

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

02. Ans: (d)

Sol: Detention time is

Volume of setting tank = Q × D.T

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

Common data question for Q3 and Q4

03. Ans: (c)

Sol: **Q =** 1.8 MLD

D.T = 4 hours

V = ?

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

Volume of tank = Q×DT

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

04. Ans: (b)

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

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

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

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

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

$L^2 = 150 \times 4$

L = 24.49 m

05. 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

06. Ans: (c)

Sol: Q = 100000 m^3/day

Settling velocity = 20 m /day

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

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

07. Ans: (a)

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

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

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

= 0.056 cm/sec

08. Ans: 27.08

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

= 12 $m^3/hr/m^2$

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

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

V_S = 0.922 mm/sec

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

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

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

$$= \frac{9.02\times10^{-4}}{3.33\times10^{-3}}\times100 = 27.08\%$$

Common Data for Qs. 09 & 10

09. Ans: (a)

Sol: d = 26 m with H = 2.10 m

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

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

10. Ans: (d)

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

$$= \frac{13000}{\pi\times26} = 159\ m^3/day/m$$

11. Ans: 44.5, 14.83 & 0.47

Sol: d = 50 μm = 50 × 10^{-3} mm = 0.05 mm,

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

L:B = 3:1, d = 3 m, $\nu = 1.01\times10^{-6}\ m^2/s$

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

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

$V_S = 1.753\times10^{-3}$ m/sec

For 100% removal

$V_S = V_0 = 1.753\times10^{-3}$ m/sec

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

L : 3B = 660.011

L × B

3B × B = 660.011

$3B^2$ = 660.011

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

L = 3 × B = 3 × 14.83 = 44.49 m

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

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

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

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

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

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

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

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

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

For 100% removal $V_S = V_0$

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

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

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

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

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

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

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

13. Ans: (c)

Sol: H = 3 m, surface area = 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 = ?

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

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

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

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

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

Proportion of particle removed 'η'

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

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

Common data for Question Nos. 14 & 15

14. 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

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

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

15. Ans: (b)

Sol: $\eta = 100\%$

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

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

$= 2.65 \times 998.2$

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

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

d = 0.016 mm

16. 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 $m^3/m^2/d$

= 0.5 mm/s

Particle	Percentage (P_i)	V_S mm/sec	$\eta = \frac{V_S}{V_0}\times 100$ %
1	10	0.1	$\eta_1 = \frac{0.1}{0.5}\times 100 = 20$
2	60	0.2	$\eta_2 = \frac{0.2}{0.5}\times 100 = 40$
3	30	1.0	$\eta_3 = \frac{1}{0.5}\times 100 = 200$ ≈ 100%

Overall removal = $\Sigma P_i\, \eta_i$

$$= \frac{10}{100}\times 20 + \frac{60}{100}\times 40 + \frac{30}{100}\times 100 = 56\%$$

17. Ans: (b)

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

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

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

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

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

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

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

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

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

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

d = 0.02 mm

18. Ans: 3.1214

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

$g = 9.8\ m/sec^2$

G = 2.65

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

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

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

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

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

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

19. Ans: 22.576

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

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

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

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

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

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

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

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

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

$= 22.576\ \mu m$

20. 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

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

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

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

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

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

$$= 112.66\ m^3/day/m$$

21. Ans: (b)

Sol:

Particle	$\frac{\text{Settling velocity}}{(m/hr)}$	**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*

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

Concentration of particle removed = 165 mg/*l*

05. Coagulation

Common Data Question 1 & 2

01. Ans: (c)

Sol: $Q = 10MLD = 10\times 10^6$ Lit/day

Alum = 20 mg/Lit

1 mg of Alum requires 0.45 mg of Alkalinity as $caco_3$

$\therefore$ 20 mg/Lit of alum requires

$= 20\times0.45 = 9$ mg of alkalinity as $caco_3$ per Lt of water

$\therefore$ Total alkalinity matching filter

Alum = 9 mg/Lit

$= 10\times10^6$ Lit /day $= 90\times10^6$

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

$= 3 \times 0.56 = 1.68$ mg/Lt

Note: Genrally quick lime(Cao, external alkali) is added to water

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: Total quantity of water to be treated = 12 MLD

Alum dose requirement = 14 ppm

Co_2 gas = ?

Total alum requirement/day

$= Q \times$ alum dose

$= 12 \times 14 = 168$ kg/day

$Al_2(So_4)_3\ 18\ H_2o + Ca(HCO_3)_2$

$\rightarrow 3CaSo_4 + 2Al(OH)_3 + 6CO_2 + 18H_20$

Molecular weight of alum = 666

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

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

$= 264$

666 parts alum release = 264 parts of CO_2

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

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

$= 5.54$ mg/*l* of CO_2

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

Sol: Q = 12 MLD

Dosage of ferrous sulphate 10 mg/*l*

Total quantity of ferrous sulphate and lime-?

$= FeSO_4 . 7H_2O$

Total quantity of ferrous sulphate req/day

$= Q \times$ dosage of ferrous sulphate

$= 10 \times 12 = 120$ 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

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

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

= 2.14 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: $G = \sqrt{\frac{p}{V\mu}}$

$$100 = \sqrt{\frac{p}{1800 \times 0.798 \times 10^{-3}}}$$

$P = (100)^2 \times 1800 \times 0.798 \times 10^{-3}$

=14364watt

= 14.364 kw

07. Ans: (d)

Sol: Q = 28800 m^3/d; ρ_w = 1000 kg/m^3

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

DT = 2 min

Volume of mixing basin = Q × DT

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

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

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

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

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

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

L = 2B

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

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

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

P = 1613.92 watts

9. Refer Previous GATE solutions Book

10. Ans: (b)

Sol: Q = 4.2 m^3/min

V_0 = 0.2 mm/sec;

d = 3.5 m

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

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

A = 350 m^2

06. Filtration

01. Ans: 35.35 m, 17.67 m

Sol: P = 50,000 person

ROF = 180 lit/hr/m^2

Q = Population × per capita demand

Q = 50,000 × 150 = 7500000 lit/day

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

= 1.8 × 7500000

= 135 × 10^5 lit/day

ROF = 180 lit/hr/m^2

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

$= \frac{135\times10^5}{24\times180}\ \frac{lit/hr}{lit/hr/m^2} = 3125\ m^2$

No. of filters in operations = 5

(1 act as stand by)

Area of each filter L × B

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

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

L : B = 2 : 1 ⇒ L = 2B

2B × B = 625 m^2

B^2 = 625/2

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

L = 35.35 m

02. Ans: 11

Sol: Treated water Q = 10 MLD

$= 10\times10^3\ m^3/day$

Rate of filtration RDF = 200 lit/hr/m^2

$= 200\times10^{-3}\times24\ m^3/day/m^2$

Total area required to treat water

$= \frac{Q}{RDF} = \frac{10\times10^3}{200\times10^{-3}\times24}$

= 2083.33 m^2

Area of each filter = 20 ×10 M^2

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

$= \frac{2083.33}{200}$

= 10.41 ≃ 11 numbers

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

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

L.B = 2 : 1

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

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

No. of filters = 1

Area of filter = 200 m^2

$L \times B = 200 \quad \left\{\because \frac{L}{B} = \frac{2}{1}\right\}$

2B × B = 200

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

L = 2 × 10 = 20 m

Volume of water filter b/w back wash = ROF × duration of filtration × area of each filter

$= 5 \times \left(24 - \frac{10}{60}\right) \times 200 = 23833.33 m^3$

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

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

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

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

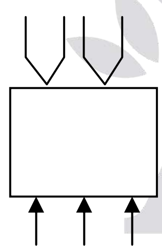
Sol: Q = 0.25 m^3/sec, No. of filters = 4,

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

Back wash rate, 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 × B = 45

2B × B = 45

$2B^2 = 45$

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

L = 2 × 4.74 = 9.48 m

= 10 × 45 = 450 liter/sec = 0.45 m^3/sec

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 $= \frac{Q}{2}$

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

05. Ans: 0.27 m

Sol: $V_1 = i_r = 3.0$ m/hr

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

d = 0.5 mm $\quad$ n = 0.4

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

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

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

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

$= \frac{150(1-0.4)}{0.33} + 1.75 = 271.75$

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

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

= 0.251 m

06. Ans: 0.032 m/sec, 0.6258 m

Sol: d = 0.65 mm, G = 2.66, n = 0.42,

z = 65 cm = 0.65 m

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

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

= 0.29 mm/sec

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

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

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

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

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

$n_e = 0.613$

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

Head loss during back wash h_b

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

$= 0.6258$ m

07. Ans: (a)

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

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

$Z_2 = ?$

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

$$46.06 = \frac{1}{z_0}\times4.606$$

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

$Z_2 = 0.10$ m

Common data for Question Nos. 08 & 09

08. 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 mm^2

09. Ans: (c)

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

Total no. of filters = 6

10. 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

11. 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

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

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

12. Refer Previous GATE solutions Book

13. Refer Previous GATE solutions Book

14. Refer Previous GATE solutions Book

07. Disinfection

01. Ans: 51.2 sec

Sol: $N_o = 10^6$

$N_t = 100$ $\left[\because \ell n\left(\frac{N_t}{N_o}\right) = -kt\right]$

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

t = 51.16 sec

02. Ans: (c)

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

Q = 20,000 × 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 × 0.66 = 1.98 = 2 kg/day

03. Ans: (c)

Sol: Cl_2 = 20,000 Cu m
8 kg. residual after 10 min = 0.15 mg/l

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

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

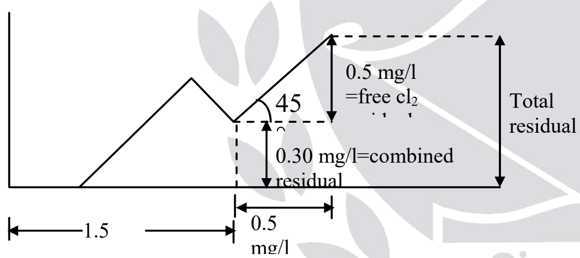
Dose of $Cl_2 = \dfrac{8}{20} = 0.4$ mg/l

Cl_2 demand = Cl_2 dose – Residual Cl_2

= 0.4 – 0.15 = 0.25 mg/l

04. Ans: (b)

Sol:



Total residual = 0.3 + 0.5 = 0.80 mg/l

05. Ans: (b)

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

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

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

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

$\Rightarrow P^H = 6.614$

08. Ans: (d)

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

Cl_2 dose = 0.1 mg/l

Volume of water to be treated = 200 ml

Total amount of Bleaching powder required =?

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

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

Total bleaching powder required

= bleaching powder dose × Volume of water

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

09. Ans: 3.2 min

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

t = ?

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

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

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

Solving

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

= 3.2 min

10. Ans: (c)

Sol: Percent removal $(\%R)$

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

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

11. Ans: (a)

Sol: Free residual

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

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

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

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

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

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

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

$$\therefore HOCL = OCL^-$$

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

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

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

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

12. Ans: (b)

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

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

k = 2.5×10^{-8} mol/lit

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

13. Ans: (a)

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

C → Concentration of disinfectant

t → detention time (or) contact time

n → dilution factor.

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

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

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

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

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

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

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

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

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

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

$\therefore$ Total chlorine required for 22 MLD

$= Q_2 \times C_2$

$= 22\times 2.75$

$= 60.5$ kg/day

14. Ans: 50.02 m^3

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

K = 0.145

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

$\Rightarrow t = 26.979$ min

Contact time "t" = detention time

= 7.0358 min

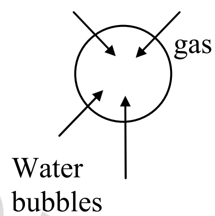
Volume of disinfection unit $= Q\times Dt$

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

08. Miscellaneous Water Treatment

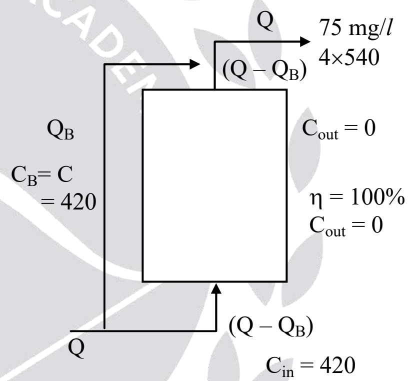
05. Ans: (b)

Sol: liquid –gas system absorption.



08. Ans: 385.714

Sol:



$C_{in} = 420$ mg/l

$C_{out} = 75$ mg/l

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

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

$= 82.142\%$

$\eta = 100\%$

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

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

$= 385.714$ lit/day

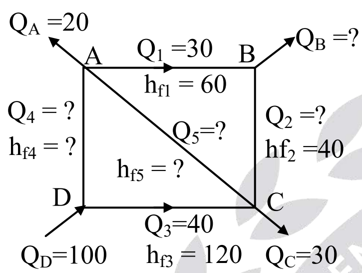
Flow that can be by passed = 385.714 Lit/day

09. Distribution System

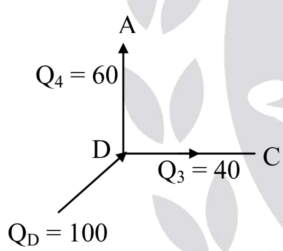
03.

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

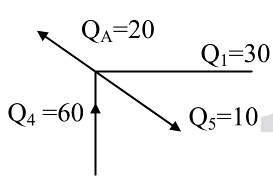
$Q_5 = 10$; $h_{f5} = 20$; $h_{f4} = 100$



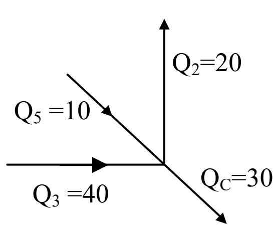
Consider junction 'D', unknown is Q_4



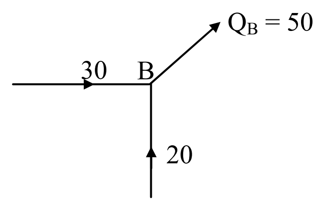
Consider junction A, unknown is Q_5



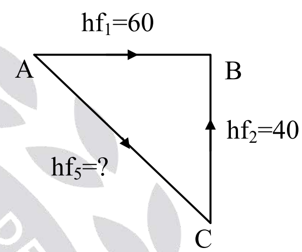
Consider junction C, unknown is Q_2



Consider junction B, unknown is Q_B



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

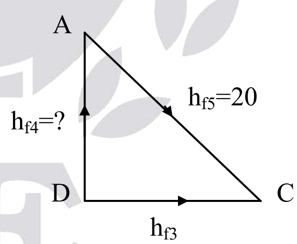


$$+h_{f1} - h_{f2} - h_{f5} = 0$$

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

$$h_{f5} = 20$$

Consider loop ACDA



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

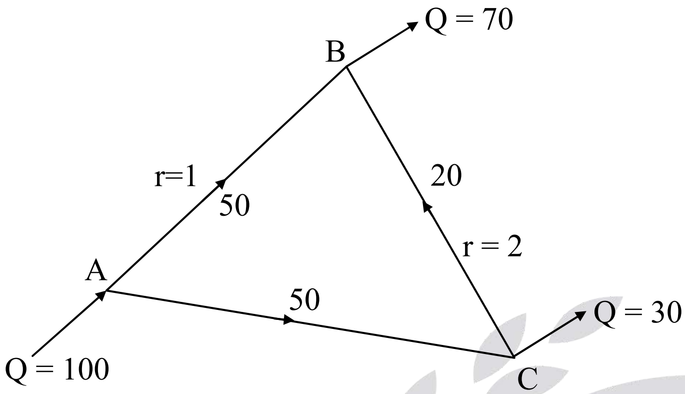
$$+h_{f5} - h_{f3} + h_{f4} = 0$$

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

$$h_{f4} = 100$$

06. Ans: 0.615

Sol :



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

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

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

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

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

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

$$r_{AC} = 0.615$$

Waste Water Engineering

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

01. Ans: (b)

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

02. Ans: (a)

Sol: $\text{Intensity}(I) = \dfrac{\sum A_i \times I_i}{A}$

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

$= 0.41$

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

I = 0.41

R = 5 cm/hr = 50 mm/hr

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

03. Ans: 0.1736 m³/sec, 2.015 m³/sec

Sol: Population = 1,00,000

Q_{Dwf} = Population × percapita × factor

= 1,00,000 × 200 × 0.75

= 15 × 10^6 lpcd = 15 MLD

= 0.1736 m^3/sec

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

= 14.51 mm/hr

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

04. Ans: 2.508 m³/sec

Sol: P = 40000

A = 75 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

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

Q_{wwf} = 2.47 m^3/sec

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

Combined discharge = 0.0388 + 2.470

= 2.5088 m^3/sec

05. Ans: 0.323 m³/sec

Sol: A = 1 km² = 100 ha;

P = 1000 no/ha

Rate of flow = 200 *l*pcd

Factor = 0.80

P = 100000

$$I = \frac{1.2\times10}{24} = 0.5\,mm/hr$$

$$Q_{DWF} = \frac{100000\times200\times0.80\times10^{-3}}{24\times3600}$$

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

R = 0.5 mm/h

$$Q_{WWF} = \frac{AIR}{360} = \frac{100\times1\times0.5}{360}$$

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

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

$= 0.185 + 0.138 = 0.323\ m^3/sec$

02. Design of Sewers

02. Ans: 1.311 m

Sol: A = 150 ha

P = 50,000

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

t_e = 5 min

t_f = 20 min

Q = 270 *l*t/d/c

Impermissibility factor = 0.45

Factor = 0.75

$Q_{DWF} = 50000 \times 270 \times 0.75$

$= 0.117\ m^3/sec$

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

$$= \frac{150\times0.45\times22.57}{360}$$

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

= 4.23

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

$= 4.34\ m^3/sec$

Q = AV

$$4.34 = \frac{\pi}{4}\times D^2\times3.2$$

$$D^2 = \frac{4\times4.34}{\pi\times3.2} = 1.72$$

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

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

S = ?

Running full

n = 0.012 Factor = 0.80

Rate of water supply = 150 *l*pcd

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

$$Q_{DWF} = \frac{30000\times150\times0.80}{24\times10^3\times60\times60}$$

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

$Q_{design} = 3.5\times 0.0416$

$= 0.1456\ m^3/sec$

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: Q = ?

d = 1.25 m

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

Half-full

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

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

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

$Q = 1.35\ m^3/sec$

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

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

$$V_{self} = \sqrt{\frac{8\times0.1}{0.03}(2.65-1)\times9.81\times1\times10^{-3}}$$

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

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

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

$$S = 4.63\times10^{-4} = \frac{1}{2159}$$

S = 1 in 2159 ≃ 1 in 2160

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

Sol: dia of sewer D = ?

n = 0.013

Q = 0.05 m^3/sec

S = 1 in 1000

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 × 0.05 = 0.027 m^3/sec

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

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

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

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

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

10. Ans: (c)

Sol: D = 300 mm ;

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

n = 0.015 ;

S = 1/280

To find 'Q'

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

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

$= 0.05\ m^3/sec$

$= 4320\ m^3/day$

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

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

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

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

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

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

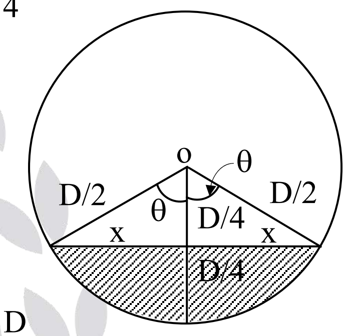
$\therefore\ \frac{\vartheta}{V} = 0.8$

$\vartheta = 0.8 \times 0.708 = 0.57$ m/sec

11. Ans: (c)

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

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



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

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

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

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

$\theta = 60^o$

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 = $0.25d^{-1}$

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

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

$(D_0)_I = 8.428$ mg/l

$y_5^{20^0C} = [(D_0)_I - (D_0)_F] \times D.F$

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

= 151.4 mg/l

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

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

$y_t^{20^0C} = 151.4 = L_0\left(1 - e^{K_{20} \times 0}\right)$

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

L_0 = Ultimate BOD 'L_0' = 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

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

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

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

$= (8.4 - 3.80) \times 20 = 92$ 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

$y_5^{30^0C} = L_0\left(1 - e^{-K_t t}\right)$

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

K_{20} (base 10) = 0.1 d^{-1} = 2.3 × 0.1

$= 0.23d^{-1}$

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

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

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

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

$= 0.364d^{-1}$

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

$L_0 = 131.78$ mg/l

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

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

05. Ans: 246.36 mg/*l*

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

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

$= 2.3 \times 0.1$

$= 0.23d^{-1}$

$y_1^{30^0C} = L_0\left(1 - e^{-0.364\times1}\right)$

$110 = L_0(1-e^{-364.\times1})$

$L_0 = 360.5$ mg/*l*

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

$= 0.364d^{-1}$

$y_5^{20} = L_0(1 - e^{-K_{20}\times0})$

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

06. Ans: 304000

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

compute daily 5 day O_2 demand

Total strength of waste = Q × y

= 80 × 285

= 22800 kg/day

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

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

$$\text{Per} = \frac{22800}{75\times10^{-3}} = \frac{\text{kg/day}}{\text{kg/day}}$$

Population equation = 304000 persons

07. Ans: 93.72%

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

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

$Sr = 93.72\%$

08. Ans: 1%

Sol: $BOD_5 = 600$ mg/*l*,

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

BOD_u remain unaxidised after 20 days =?

$y_5^{20^0C} = L_0\left(1 - e^{K_t t}\right)$

$600 = L_0(1-e^{-0.23\times5})$

$L_0 = 878.01$ mg/*l*

$L_{20} = L_0e^{-Kt}$

$= 878.01 \times e^{Kt}$

$= 878.01 \times e^{-0.23\times20} = 8.82$ mg/*l*

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

1% of BOD after 20 days

09. Ans: (a)

Sol:

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

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

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

$= [9.2 - 6.9] \times 60 = 138$ mg/*l*

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

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

10. Ans: (c)

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

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

$= 0.24\ h^{-1}$

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

$190 = L_0(1 - e^{-0.0124\times5})$

$L_0 = \dfrac{190}{\left(1 - e^{0.24\times5}\right)} = 271.89$ mg/l

11. Ans: (d)

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

BOD = 2.5 day

$\left[y_5^{20} = L_0\left(1 - e^{-0.18\times5}\right)\right]$

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

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

$L_0(1 - e^{-K_{20}\times5}) = L_o(1 - e^{-K_T\times2.5})$

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

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

(T-20)Ln(1.047)=Ln2

(T-20)0.045 = 0.693

$T = 35^0C$

12. Ans: (c)

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

BOD = 10 days = ?

$y_3^{20} = L_0(1 - e^{-0.345\times3})$

$L_0 = 116.31$ mg/l

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

$L_t = 112.61$ mg/l

$L_0 - L_t = 116.31 - 112.61 = 3.7$ mg/l

14. Ans: (b)

Sol: $y_5^{20^oC} = 200$ mg/l

$y_5^{30^oC} > y_5^{20^oC}$

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

15. Ans: (c)

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

16. Ans: (b)

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

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

17. Ans: (a)

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

18. Ans: (c)

Sol: y = 162 mg/l

$Q = 1000\ m^3$/day

Q = 1000 × 1000 $l$pcd = 1 MLD

Per capita BOD = 80 gm/capita

Population equivalent

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

$= \dfrac{Q\,y}{80\times10^{-3}} = \dfrac{1\times162}{80\times10^{-3}} = 2025$

19. Ans: (b)

Sol: $[(D_0)]_1 = 8$ mg/l , $(D_0)_f = 2$mg/l

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

5 days BOD = $[(D_0)_I - (D_F)] \times$ D.F

= (8–2) × 150

= 900 mg/l

20. Ans: (a)

Sol: Ferroin is used as indicator in COD test

21. Ans: (c)

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

y_5^{30} = 250 mg/l

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

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

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

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

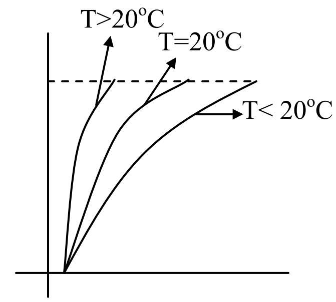
$K_{20} \times 5 = K_{30} \times t$

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

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

22. Ans: (a)

Sol:



T> 20°C curve shift to the left

23. Ans: 128.1 mg/l

Sol: $y_5^{20°}$ = ?

$y_7^{20°} = 150\,\text{mg}/\ell$

K = 0.23d^{-1}

150 = L_o (1 – $e^{-23 \times 7}$)

L_o = 187.47 mg/l

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

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

$y_5^{20°} = 128.11\,\text{mg}/\ell$

24. Refer Previous GATE solutions Book

04. Treatment of Sewage

02. Ans: (d)

Sol: 12 m × 1.50, H = 0.8 m, Q = 720 m^3/hr

L = 12 m, B = 1.50 m

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

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

$$= 40000\ lit/hr/m^2$$

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

$$= \frac{12\times1.5\times0.8}{\frac{720}{60}} = 1.2\ min$$

04. Ans: (b)

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

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

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

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

05. Ans: (b)

Sol: G = 2.70

d = 0.21 mm

V_s = ?

$\upsilon = 1\times10^{-2}\ cm^2/sec = 1\times10^{-6}\ m^2/sec$

For laminar flow condition

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

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

V_s = 0.04089 m/sec

V_s = 4.089 cm/sec

06. Ans: (b)

Sol: L = 7.5 m

V_H = 0.3 m/sec

H = 0.9m

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

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

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

$\Rightarrow V_S = 0.036$ m/sec

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

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

d = 0.21 mm

07. Ans: (a)

Sol: V_H = 0.25 m/s

D.T = 1 minute

$L = V_H \times D.T$

= 0.25 × 1 × 60

= 15 m

08. Ans: (d)

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

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

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

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

$d = 13.5\ m$

09. Refer Previous GATE solutions 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

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

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

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

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

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

$V = 16363\ m^3$

02. Ans: (d)

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

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

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

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

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

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

03. Ans: (a)

Sol: $X = 2000\ mg/l$

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

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

Common Data for Question Nos. 4 to 7

04. Ans: (c)

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

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

MLSS = 2500 mg/l

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

05. Ans: (b)

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

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

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

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

$$= \frac{10900 \times 2500}{220 \times 9700 + (35000-220)30}\ m^3 \times \frac{mg}{l}$$

=8.57 days

08. Ans: (c)

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

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

09. Ans: (d)

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

Total amount of MLSS in aeration

Tank = VX

= m^3 (mg/l)

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

= 400 kg

11. 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 12 & 13

12. Ans: (c)

Sol: Given,

$Q = 500\ m^3/h$

$y_i = 150$ mg/l

$y_e = 10$ mg/l

D T = 8 hours

Q_C = 240 hours

$V = 4000\ m^3$

X = 2000 mg/l

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

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

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

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

13. Ans: (c)

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

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

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

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

= 800 kg/day

14. 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

16. Ans: 7.5 days

Sol: From the data $X = 3000$ mg/lit

$Q_w = 50$ m^3/day

$X_u = 1000$ mg/lit

$Q - Q_w = 14950$ m^3/day

$\Rightarrow$ $Q - 50 = 14950$ m^3/day

$Q = 15,000$ m^3/day

$V = Q\times D.T$

$= 15,000 \times 2$hr

$$= 15,000\times\frac{2}{24} = 1250\ m^3$$

$$\theta_c = \frac{VX}{Q_w x_u + (Q - Q_w)x_e}$$

$$\theta_c = \frac{1250\times 3000}{50\times 10,000 + (14950)\times 0}$$

= 7.5 days

17. 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

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

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

$$VX = 6\times 10^6$$

(I) Volume of aeration tank

$$V = \frac{6\times 10^6}{3\times 10^3} \qquad (\because X = 3000\ mg/lit)$$

$\therefore$ Volume = 2000 m^3

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

= 4.8 hours

(III) B.O.D removal efficiency

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

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

$\eta = 86.66\%$

(IV) Volumetric loading rate

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

$$= 0.75 \text{ kg/day/m}^3$$

(V) Mass of sludge wasted per day

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

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

$\therefore$ 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

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

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

$Q_w = 60 \text{ m}^3/\text{day}$

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

S.V.I = 100

(VIII) $\frac{Q_R}{Q}$ = Recycling ratio $= \frac{X}{X_w - X}$

$$\Rightarrow \frac{Q_R}{Q} = \frac{3000}{10000 - 3000} = 0.4285$$

(IX) $\therefore$ Rate of return sludge

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

$Q_R = 4285 \text{ m}^3/\text{day}$

18. Refer Previous GATE solutions Book

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

Depth of TF = ?

Vol. of TF = ?

SLR = 2500 *l*/m^2/day

η = ?

y_e = ?

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

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

d = 55.27 m

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

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

V = 5142.85 m^3

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

$$d = \frac{5142.85}{2400}$$

d = 2.14 m

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

OLR = 1750 kg/ha. m/day

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

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

η = 84.45%

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

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

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

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

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

F = 2.017

Q = 2200 m^3/day

Q = 2200 $\times$1000 *l*pcd

Q = 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 Previous GATE solutions Book

07. Sludge Digestion

01. Ans: 17105.62 kg/day, 16.68m^3/day

Sol: Q = 4.5 MLD

Total dry solids = Q ×sewage containing

= 4.5 × 275= 1237.5 kg

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

$1.02 = \frac{\rho_{Sludge}}{\rho_w}$

ρ_{sludge} = 1.02 ×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: $\frac{V_2}{V_1}=\frac{100-P_1}{100-P_2}$

$= \frac{100-99}{100-96} = 25\%$

% of reduction is volume = 100 V_1–25V_1

= 75% V_1

05. Ans: (d)

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

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

07. 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

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

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

$\Rightarrow S_{solids} = 2.329 \simeq 2.4$

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

$\therefore \frac{100}{S_s} = \frac{2}{S_{solids}} + \frac{98}{S_{water}} \Rightarrow \frac{100}{S_s} = \frac{2}{2.4} + \frac{98}{1}$

$\Rightarrow S_s = 1.011;\ \rho_s = 1011$ kg/m^3

08. Ans: (c)

Sol: P_1 = 94% Solid content = 16%

P_2 = 84% Water content = 100 – 16 = 84%

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

$= \frac{100-94}{100-84}\times 14 = 5.25$ m^3

08. Septic Tanks

01. Ans: 6.12 m × 3.16 m

Sol: Discharge = 150 × 200 × 10^{-3} = 30 m^3/day

Given detention time = 24 hours

$\therefore$ Volume of septic tank (v) = t×Q

$= \frac{(24)(30)}{24}$

= 30 m^3

$\therefore$ Area of septic tank $= \frac{(30)}{(1.5)} = 20$ m^2

$\therefore$ Given $\frac{L}{B} = 2:1$

L × B = 20

2B × B = 20

B = 3.16 m

and L = 6.12 m

02. Ans: 0.6 m

Sol: Volume of sludge produced

= 30×10^{-3}×200×2

= 12 m^3

$\therefore$ depth of sludge zone

$= \frac{\text{Volume of sludge}}{\text{Area of septic tank}}$

$= \frac{12}{20} = 0.6$m

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

Sol: Given sewage flow = 150 *l*pcd

Sewage discharge = $150 \times 10^{-3} \times 120$ m^3/day

= 18 m^3/day

Detention period = $\frac{V}{Q} = \frac{4\times2\times1.5}{18 m^3/day} = 16 hrs$

(a) Volume of sludge = (Q × detention time)

= $40 \times 10^{-3} \times 120 \times 2$

V = 9.6 m^3

(b) Volume of soakpit

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

$= \frac{(150\times120)}{(1500)} = 12\ m^3$

04. 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

$\frac{7}{2} = 70\times10^{-3}\times5\times C.P$

$C.P = \frac{7/2}{70\times10^{-3}\times5}$

= 10 years

09. Oxidation Ponds

01. Ans: L = 282.84m, B = 70.71m, D.T. = 50 days

Sol: Q = population × per capita, supply×Factor

= 10,000× 100×0.8

$= \frac{1000000\times0.8}{10^6} = 0.80 MLD$

y = 40 g/day

D.T = ?

80% of BOD removal BOD loading rate

= 200 kg = BOD/hect/d

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

$= \frac{0.8\times500}{200} = 2$ ha

Total BOD = Q $\times y_i$

= population × per capita BOD

= $0.8 \times y_i = 10{,}000 \times 10040 \times 10^{-3}$

y_i = 500 mg/li

Surface area = 2 ha = 2×10^4 m^2

L = 4B

L × B = 2×10^4

4B × B = 2×10^4

$B = \sqrt{\frac{2\times10^4}{4}} = 70.71$ m

L = 4 × 70.71 = 282.84 m

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

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

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

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

$$0.8 = \frac{500.y_e}{500} \Rightarrow 400 = 500 - y_e$$

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

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

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

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

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

OLR = 300 kg/ha/d

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

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

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

$L \times B = 1.5 \times 10^4 \text{ m}^2$

$4B \times B = 1.5 \times 10^4$

B = 61.23 m

$\therefore$ L = 4 ×61.23 = 244.92 m

Vol of oxidation pond = Q ×DT

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

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

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

04. Ans: (c)

Sol: Q = 10000 × 200, y = 300 mg/l

Organic loading = 310 kg/day/m

Q = 2 MLD

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

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

10. Disposal of Sewage Effluents

01. Ans: (b)

Sol: $y_R = 200$ mg/l, $Q_R = 50$ m^3/s

$y_w = 8$ mg/l, $Q_w = 500$ m^3/s

$$y_{mix} = \frac{Q_R y_R + Q_w y_w}{Q_R + Q_w}$$

$$= \frac{50 \times 200 + 500 \times 8}{50 + 500}$$

$y_{mix} = 25.45$ mg/l

02. 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

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

$$(DO)_{mix} = \frac{2 \times 1.10 + 8.3 \times 8.70}{1.10 + 8.70}$$

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

03. Ans: 13.85 mg/l, 20.27 mg/l , 5.85 mg/l

Sol: $Q_{Rw} = 12000$ m^3/d, temp = 20^{0}C,

$y_w = 50$ mg/l

D.O = concentration = 2 mg/l

$Q_R = 40,000$ m^3/d, $y_R = 3$ mg/l,

D.O = 7 mg/l, temp = 20^{0}C

K = 0.23 (to the base in decay curve)

$$y_{mix} = \frac{Q_R y_R + Q_w y_w}{Q_R + Q_w}$$

$$= \frac{12000 \times 50 + 40,000 \times 3}{12,000 + 40,000} = 13.84 \text{mg/lit}$$

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

$$= \frac{12,000 \times 2 + 40,000 \times 7}{12,000 + 40,000}$$

$= 5.85$ mg/l

$y_{mix} = L_0(1-e^{-k\times t})$

$$13.85 = L_0(1-e^{-0.23\times 5}) = \frac{13.85}{(1 - e^{-0.23\times 5})}$$

$L_0 = 20.27$ mg/l

04. Ans: (c)

Sol:

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

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

$$= \frac{12 \times 5 + 2 \times 90}{12 + 2} = 17.142 \text{ mg}/l$$

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

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

Time taken by the river to travel 10 km

$$= \frac{10 \times 1000}{0.28} \times \frac{1}{24 \times 50 \times 60}$$

T = 0.413 days

Ultimate BOD at 10 km d/s = $L_t = L_o\, e^{-kt}$

k = 0.25 1/day

$L_{0.413} = 17.142\, e^{-0.25 \times 0.413} = 15.459$

$\simeq 15.46$ mg/l

05. Refer Previous GATE solutions Book

06. Refer Previous GATE solutions Book

11. Solid Waste Management

01. Ans: 3870

Sol: Total energy as discarded

$$= \frac{\Sigma P_i E_i}{100} = \frac{P_1E_1 + P_2E_2 + \ldots\ldots\ldots + P_nE_n}{100}$$

$$= \frac{[20\times 2500 + 10\times 10000 + 10\times 8000 + 10\times 14000 + 40\times 3500 + 5\times 14000 + 5\times 100]}{100}$$

= 5805 kJ/kg

Moisture content of MSW

$$= \frac{20\times 70 + 10\times 4 + 10\times 4 + 10\times 1 + 40\times 60 + 5\times 20\times 2 + 5\times 2}{100}$$

= 40%

Total energy on dry basis

$$= \text{energy as discarded} \times \frac{100}{100 - \%mc}$$

$$= 5805 \times \frac{100}{100-40} = 9675 \text{ kJ/kg}$$

Difference in energy content = 9675 – 5805

= 3870 kJ/kg

02. Ans: (b)

Sol: $$\frac{100}{\rho Msw} = \frac{\%F.w}{\rho Fw} + \frac{\%DA}{\rho DA} + \frac{\%pla}{\rho p} + \frac{\%WS}{\rho WS}$$

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

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

$\rho Msw = 217.1$ kg/m^3

04. Ans: (d)

Sol: 50 g of Co_2, 25 g = CH_4, 1 million people, rate of 500 ton/day

120 parts of MSW release 50 parts of Co_2 and 25 parts CH_4 1 part of MSW release

$$= \frac{75}{120} = 0.625 \text{ parts of green house}$$

500 t of Msw release = 0.625 × 500

Total green house = 321.5 of green house

Per capita green house gas contribution

$$= \frac{\text{house gas}}{\text{population of community}}$$

$$= \frac{312.5}{10{,}00{,}000} \times 1000 \times 1000$$

= 312.5 mg/l

07. Ans: (d)

Sol: Indore method is aerobic method & Bangalore method is anaerobic method of composting.

08. Ans: (c)

Sol: Plastic & rubber waste is disposed by pyrolysis. (burning in the absence of air) to recover by products.

09. Ans: (d)

Sol: 40t + 35t = 75t

10. Ans: (b)

Sol: Except human excreta all forms of solid waste is treated as refuse.

11. Ans: 1.46 ha

Sol: Population = 65000

Rate of solid waste = 2 kg/capita/day

Solid waste generated = 65000 ×2

= 130000 kg/day

Solid waste generator per annum

= 130000×365 = 47450000

$$\text{Volume} = \frac{\text{mass}}{\text{density}}$$

$$V = \frac{47450000}{650} = 73000\ m^3$$

$$\text{Area} = \frac{\text{Volume}}{\text{depth}} = \frac{73000}{5}$$

$A = 14600\ m^2 = 1.46$ ha

12. Ans: (a)

Sol: $$\frac{100}{\rho_{sludge}} = \frac{c_1}{\rho_1} + \frac{c_2}{\rho_2}$$

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

13. Ans: 13.6875

Sol: Solid waste generated = $2 \times 10^5 \times 25 \times 365 \times 2$

$= 3.65 \times 10^9$ kg

Volume of un-compacted

$$S_w = \frac{3.65\times10^9}{100} = 36.5 \times 10^6\ m^3$$

Volume of compacted solid waste

$$= \frac{36.5\times10^6}{4} = 9.125 \times 10^6\ m^3$$

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

Volume of land fill (compacted fill)

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

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

14. Refer Previous GATE solutions Book

12. Air Pollution and Control

05. Ans: (d)

Sol: $CHCl_3 = 12 + 1 + 3\times35.5$

= 119.5 gm molecular.

Concentration = $0.4\ \mu g/m^3$

@ 273^0 k

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

$P_1 = 1$ $\quad$ $P_e = 1$

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

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

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

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

$$0.4 = \frac{\text{PPm} \times 119.5 \times 10^3}{24.04}$$

PPM = $8.047\times10^{-5} \times 10^3$ $[\because 1\text{billion} = 10^9]$

= 0.08

Parts per billion = $8.047 \times10^{-5} \times10^3 = 0.08$

07. 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

08. Ans: (c)

Sol: Initial dry cot = 9.787 g, rate

$= 1.5\ m^3/min$ for $24\ m^3$

Final = 10.283 g

$$= \frac{(w_{Initial} - w_{final})}{\text{Volume of air sample}} \text{ filter paper}$$

Volume of are sample = rate of rate simplify × duration

$= 145 \times 24 \times 60 = 2088\ m^3$

Total suspended particulate

$$= \frac{(10.283 - 9.787)}{2088}$$

$= 2.375 \times 10^{-4}\ gm/m^3$

$= 2.375 \times 10^{-4} \times 10^6$

$= 237.5\ \mu g/m^3$

14. 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 t

15. Ans: (b)

Sol: A → Inversion

B → Sub adiabatic

C → Dry adiabatic

D → Super adiabatic

16. Ans: (a)

Sol: Looping → Unstable atmospheric plume behaviour conditions

17. Ans: (b)

Sol: during winter nights severe inversion occur.

18. Ans: (c)

Sol: (A) Acid rain → SO_2

(B) Acute toxicity → CO

(C) Ozone liberation → NO_X

(D) Green house effect → CO_2

19. Ans: (a)

Sol: Lapse rate

$$= \frac{dT}{dt} = \frac{21.25 - 15.70}{444 - 4} = 1.42/100$$

Lapse rate > ALR (-1^oC / 100 m)

(–1.42 /100 m)

∴ it is super adiabatic lapse rate.

20. Ans: (c)

Sol: ESP and fabric filters remove very fine

21. Ans: 0.011268

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

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

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

$$30\ \mu g/m^3 \text{ of } SO_2 = \frac{24.038}{64 \times 10^3} \times 30$$

$= 0.011268$ ppm

22. 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

$= \pi \times 0.45 \times 7.5$

Number of bags required $= \frac{300}{\pi \times 0.45 \times 7.5}$

$= 28.29 \simeq 29$

23. Ans: 8012.38

Sol: η of ESP is given by

$$\eta = 1 - e^{\frac{-AW}{Q}}$$

when $\eta = 96\%$ $\quad A = 5600 \text{ m}^2$

$\eta = 97\%$ $\quad A = 6100 \text{ m}^2$

$\eta = 99\%$ $\quad A = ?$

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

$0.99 = 1 - e^{\frac{-A \times 0.1063}{185}} \Rightarrow A = 8012.38 \text{ m}^2$

plate area of collector A = 8012.38 m^2

24. 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 $\times$% sulphur in Coal

$$30 \times \frac{2}{100} kg/min \times \frac{365 \times 24 \times 60}{1000} \times t/year$$

(Convert in to tonn/year)

SO_2 emission of gas =

$$30 \times \frac{2}{100} \times \frac{365 \times 24 \times 60}{1000} \left(\frac{100-6}{100}\right) = 296.45$$

/year

$S + O_2 \rightarrow SO_2$

$S = 32$

$SO_2 = 64$

32 Parts of sulphur = 64 parts of SO_2

1 Part of $SO_2 = \frac{64}{32}$ parts of SO_2

296.4 t/year of sulphur produce

$= \frac{64}{32} \times 296.4$ t/year of SO_2

SO_2 emission $= \frac{64}{32} \times 296.4$

$= 529.8$

25. Refer Previous GATE solutions Book

26. Refer Previous GATE solutions Book