

ANSWER KEY > Environmental Engineering

1. (c)	7. (b)	13. (d)	19. (c)	25. (b)
2. (b)	8. (b)	14. (a)	20. (b)	26. (a)
3. (c)	9. (d)	15. (d)	21. (a)	27. (a)
4. (d)	10. (b)	16. (a)	22. (a)	28. (a)
5. (b)	11. (b)	17. (d)	23. (b)	29. (a)
6. (c)	12. (a)	18. (b)	24. (a)	30. (b)

DETAILED EXPLANATIONS

2. (b)

Total hardness

$$\begin{aligned} \text{TH (in mg/l as CaCO}_3\text{)} &= (\text{milli. eq. of Ca}^{2+}) \times \text{eq. wt. of CaCO}_3 + (\text{milli. eq. of Mg}^{2+}) \times \text{eq. wt. of CaCO}_3 \\ &= 40 \times 50 + 20 \times 50 = 3000 \end{aligned}$$

$$\therefore \text{TH} > \text{Alkalinity}$$

$$\therefore \text{CH} = \text{Alkalinity} = 2250 \text{ mg/l as CaCO}_3$$

$$\therefore \text{NCH} = 3000 - 2250 = 750 \text{ mg/l as CaCO}_3$$

5. (b)

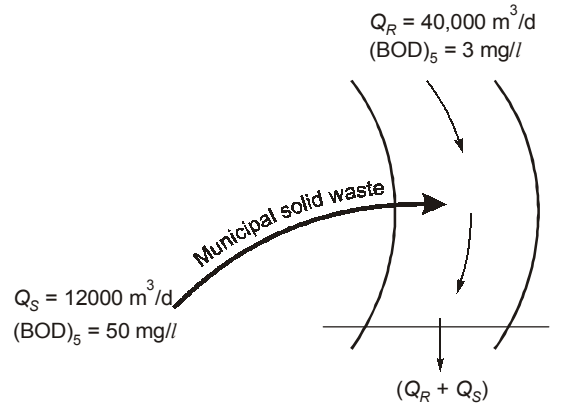
$$V_1 (100 - P_1) = V_2 (100 - P_2)$$

$$V_1 (100 - 98) = V_2 (100 - 90)$$

$$V_2 = 0.2 V_1$$

\therefore 80% decrease.

8. (b)



$$\begin{aligned}
 (\text{BOD})_{\text{mix}} &= \frac{Q_S \times (\text{BOD})_S + Q_R \times (\text{BOD})_R}{Q_R + Q_S} \\
 &= \frac{12000 \times 50 + 40000 \times 3}{12000 + 40000} \\
 &= 13.846 \approx 13.85 \text{ mg/l}
 \end{aligned}$$

9. (d)

Sanitary land filling is a site for disposal of waste material by burial. It is process of dumping of solid waste in a scientifically designed, dried, area by spreading waste in form of thin layers. It is economical, simple and efficient measure of natural decomposition of wastes.

11. (b)

Y_1 (i.e. BOD for one day) = 110 mg/lit at 30°C

$$k_D = 0.1 \text{ d}^{-1} \text{ at } 20^\circ\text{C}$$

$$\begin{aligned}
 k_{D(T=30^\circ\text{C})} &= k_{D(T=20^\circ\text{C})} (1.047)^{T-20} \\
 &= 0.1 \times (1.047)^{30-20} = 0.158 \text{ d}^{-1}
 \end{aligned}$$

$$\therefore l_0(1 - 10^{-0.158 \times 1}) = 110$$

$$l_0(\text{ultimate BOD}) = \frac{110}{1 - 10^{-0.158}} = 360.68 \text{ mg/lit}$$

Now, 5 day BOD at 20°C

$$\begin{aligned}
 Y_5 &= l_0(1 - 10^{-k_D t}) \\
 &= 360.68 (1 - 10^{-0.1 \times 5}) = 246.62 \text{ mg/lit}
 \end{aligned}$$

12. (a)

Given,

$$\text{Population} = 20,000$$

$$\text{BOD}_5 \text{ of persons} = 70 \text{ gm per capita}$$

$$\text{BOD}_5 \text{ of industry} = 450 \text{ mg/l}$$

$$\text{Discharge of industries} = 50,000 \text{ l/d}$$

Total BOD₅ of combined sewage

$$= (20,000 \times 70) + (450 \times 50,000 \times 10^{-3}) = 1422500 \text{ gm/day}$$

$$\therefore \text{Population equivalent} = \frac{\text{Total BOD}_5}{80 \text{ gm/day/person}} = \frac{1422500}{80} = 17781.25$$

13. (d)

- Fluorides are removed with aluminum oxide.
- Hexavalent chromium can be removed by reduction and followed by precipitation.
- Iron and manganese can be removed by aeration followed by coagulations, sedimentation and filtration.
- Toxic organics can be removed by activated carbon treatment.

14. (a)

Given, Drainage discharge = 1.3 m³/sec

Area of town = 20 ha

Critical rainfall intensity, $p_c = 6$ cm/hr

From, Retinol formula

$$Q_p = \frac{1}{36} k_{eq} \cdot p_c A \quad (A \text{ in ha, } P_c \text{ in cm/hr})$$

$$1.3 = \frac{1}{36} \left(\frac{k_1 A_1 + k_2 A_2 + k_3 A_3}{A_1 + A_2 + A_3} \right) \times 6 \times 20$$

$$1.3 = \frac{1}{36} \left(\frac{\left(0.8 \times \frac{x}{100} + 0.2 \times \frac{40}{100} + 0.15 \times \frac{60-x}{100} \right)}{\left(\frac{x}{100} + \frac{40}{100} + \frac{60-x}{100} \right) A} \right) \times 6 \times 20$$

$$x = 33.846 \approx 34\%$$

15. (d)

BOD loading rate = 250 kg/ha/day

Waste water flow $Q = 1$ MLD with BOD = 250 mg/lit

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

$$\therefore \text{Surface area of pond} = \frac{(1 \times 250) \text{ kg/day}}{250 \text{ kg/ha/day}} = 1 \text{ ha} \quad (\text{MLD} \times \text{mg/l} = \text{kg/day})$$

$$\therefore \text{Volume of pond (V)} = \text{Surface area} \times \text{depth} = 1 \text{ ha} \times 1 = 10^4 \times 1 = 10^4 \text{ m}^3$$

$$\therefore \text{Detention time (D}_t\text{)} = \frac{V}{Q} = \frac{10^4}{\left(\frac{1 \times 10^6}{10^3} \right)} = 10 \text{ days}$$

16. (a)

Concentration of SO₂ (in 1 μg/m³) = 42 μg/m³ at STP

$$\mu \text{g/m}^3 = \left(\frac{\text{ppm} \times \text{mol.wt} \times 10^3}{\text{volume at T}^\circ\text{C in lit/mol}} \right)$$

$$V_2 = V_1 \left(\frac{273 + 25}{273} \right) = 22.4 \left(\frac{298}{273} \right) = 24.45 \text{ lit/mol}$$

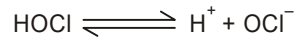
$$42 = \frac{\text{ppm} \times 64 \times 10^3}{24.45}$$

$$\text{SO}_2 \text{ (in ppm)} = 0.016 \text{ ppm}$$

17. (d)

Given, Free chlorine residual = 0.2 mg/l

i.e. $[\text{HOCl}] + [\text{OCl}^-] = 0.2 \text{ mg/l}$..(i)



$$k = 2.7 \times 10^{-8}$$

$$\text{pH} = 7.2$$

$$\Rightarrow [\text{H}^+] = 10^{-7.2}$$

$$\therefore k = \frac{[\text{H}^+][\text{OCl}^-]}{[\text{HOCl}]}$$

$$\therefore \frac{[\text{OCl}^-]}{[\text{HOCl}]} = \frac{2.7 \times 10^{-8}}{10^{-7.2}} = 0.4279$$

\(\therefore\) From equation (i)

$$[\text{OCl}^-] + \frac{[\text{OCl}^-]}{0.4279} = 0.2$$

$$[\text{OCl}^-] = 0.06 \text{ mg/l}$$

$$\therefore [\text{HOCl}] = 0.14 \text{ mg/l}$$

18. (b)

Given, Size of particle, $d = 0.025 \text{ mm}$

$$G_s = 2.65$$

Dynamic viscosity of water, $\mu = 10^{-3} \text{ N-s/m}^2$

Surface overflow rate, SOR = 0.065 cm/sec

$$\therefore \text{Settling velocity, } V_s = \frac{g}{18} (G_s - 1) \frac{d^2}{\nu} = \frac{9.81}{18} (2.65 - 1) \times \frac{(0.025 \times 10^{-3})^2}{\left(\frac{10^{-3}}{1000}\right)}$$

$$= 0.000562 \text{ m/sec}$$

$$\left[v = \frac{\mu}{\rho} \right]$$

%age of suspended particles likely to be settled in sedimentation tank i.e. efficiency of sedimentation tank

$$\eta = \frac{V_s}{V_0} \times 100 = \frac{0.000562}{0.065 \times 10^{-2}} \times 100 = 86.46\% \approx 86\%$$

19. (c)

1. Circular sewer section are mostly used for separate sewage system. But the advantage of circular sewer is obtained only when the section runs atleast half full.
2. If a circular sewer is used for combined system. It will be effective only during maximum rain water flow, but during dry weather flow, velocity generated would be very less.

20. (b)

Nitrogen in any soluble form i.e. NH_3 , NH_4^+ , NO_2^- and NO_3^- excluding N_2 gas is a nutrient and may need to be removed from waste water to help control algal growth in the receiving body.

21. (a)

As per Chick's law,

$$\frac{N_t}{N_0} = e^{-kt}$$

98% killing of bacteria; $k = 3 \times 10^{-2} \text{ s}^{-1}$

i.e.
$$\frac{N_t}{N_0} = 0.02$$

$$0.02 = e^{-3 \times 10^{-2} \times t}$$

$$t = 130.4 \text{ sec} \approx 2.17 \text{ min}$$

22. (a)

$$\text{Total solids, } \frac{0.952}{1000} \times 10^6 = 952 \text{ ppm}$$

$$\text{Fixed solids, } \frac{0.516}{1000} \times 10^6 = 516 \text{ ppm}$$

$$\begin{aligned} \text{Volatile solids} &= S_V = S_T - S_F = 952 - 516 \\ &= 436 \text{ ppm} \end{aligned}$$

23. (b)

$$V_f = 1.22 \text{ cm/sec}$$

$$G_S = 2.65$$

$$v = 0.01 \text{ cm}^2/\text{sec}$$

$$D_t = \frac{l}{V_f} = \frac{H}{V_0}$$

$$\frac{65}{1.22} = \frac{3.5}{V_0}$$

$$V_0 = \frac{3.5 \times 1.22}{65} = 0.065 \text{ cm/sec}$$

For 100% removal (let d (in cm) be the size of particle)

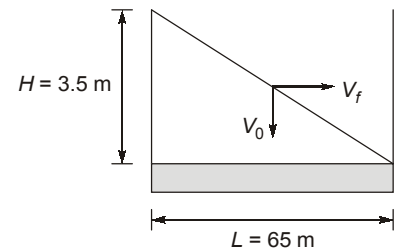
$$V_s = V_0$$

$$\frac{g}{18}(G_S - 1) \frac{d^2}{v} = V_0$$

$$\frac{981}{18}(2.65 - 1) \frac{d^2}{0.01} = 0.065$$

$$d = 0.0027 \text{ cm}$$

$$d = 0.027 \text{ mm}$$



24. (a)

Year	Population	Increase in population	%age inc.
1971	8,00,000	—	
1981	9,50,000	150000	$\frac{150000}{800000} \times 100 = 18.75 (r_1)$
1991	11,20,000	170000	$\frac{170000}{950000} \times 100 = 17.89 (r_2)$
2001	13,45,000	225000	$\frac{225000}{1120000} \times 100 = 20.09 (r_3)$

∴ Average %age increase,

$$r = (r_1 r_2 r_3)^{1/3} = (18.75 \times 17.89 \times 20.09)^{1/3}$$

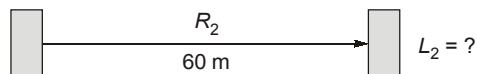
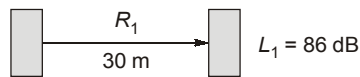
$$= 18.89\%$$

Population at the end of 2031 i.e. after 3-decades. As by geometrical increase method, we know that

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

$$P_2 = 13,45,000 \left(1 + \frac{18.89}{100}\right)^3 = 2260259$$

25. (b)



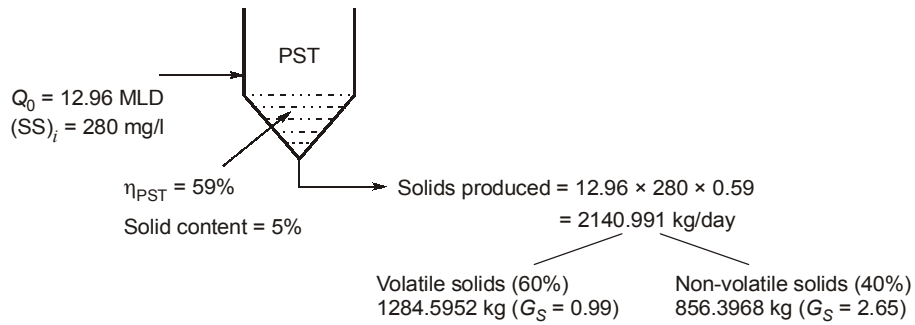
Since linear source,

∴

$$L_2 = L_1 - 10 \log_{10} \left(\frac{R_2}{R_1} \right)$$

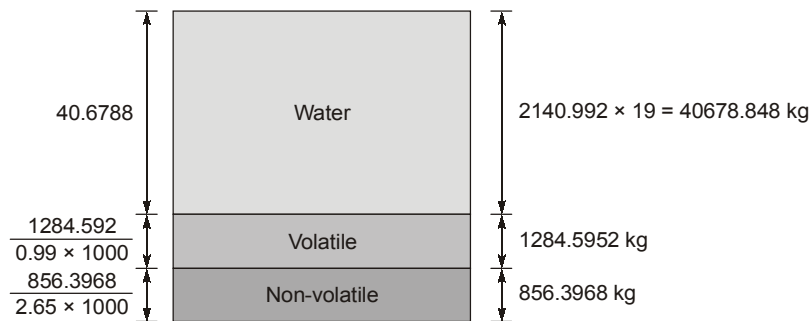
$$= 86 - 10 \log_{10} \left(\frac{60}{30} \right) = 82.98 \text{ dB}$$

26. (a)



or,

5 kg of solids \simeq 100 kg of sludge
 5 kg of solids \equiv 95 kg of water
 1 kg of solids \equiv 19 kg of water



$$\therefore \text{Daily sludge volume production} = \left(40.6788 + \frac{1284.592}{0.99 \times 1000} + \frac{856.3968}{2.65 \times 1000} \right)$$

$$= 42.299 \simeq 42 \text{ m}^3$$

27. (a)

Given,

$$Q_0 = 3.5 \text{ MLD}$$

$$(\text{BOD})S_0 = 130 \text{ mg/l}$$

$$(\text{SS})_i = 150 \text{ mg/l}$$

Dimension of aeration tank (30 m × 9 m × 4 m)

MLSS concentration $X = 1800 \text{ mg/lit}$

$$\therefore \text{BOD loading rate} = \frac{Q_0 S_0}{V} = \frac{3.5 \text{ MLD} \times 130 \text{ mg/l}}{\left(\frac{30 \times 9 \times 4}{10^4} \right) \text{ ha-m}}$$

$$= 4212.96 \text{ kg/ha-m/day} \quad (\text{MLD} \times \text{mg/l} = \text{kg/day})$$

29. (a)

Given, η (efficiency of high rate trickling filter) = 82%

Volume of filter,

$$V = 1365 \text{ m}^3 = 0.1365 \text{ ha-m}$$

Recirculation ratio,

$$R = 1.5$$

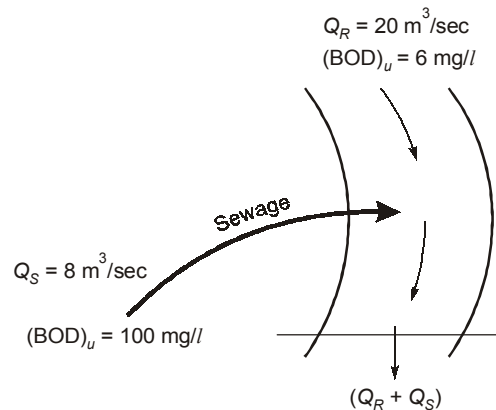
$$\eta = \frac{100}{1 + 0.0044 \sqrt{\frac{w}{VF}}}$$

$$F = \frac{1+R}{(1+0.1R)^2} = \frac{1+1.5}{(1+0.1 \times 1.5)^2} = 1.89$$

 $w = \text{BOD}_5$ (in kg/day) entering the filter

$$w = 642.105 \text{ kg/day}$$

30. (b)

Given, Cross section area of river = 80 m^2

$$\therefore \text{Velocity of river after mixing} \quad V = \frac{(20+8)}{80} = 0.35 \text{ m/sec}$$

$$(\text{BOD})_{u, \text{mix}} = \frac{Q_S (\text{BOD})_{uS} + (Q_R) \times (\text{BOD})_{uR}}{Q_S + Q_R}$$

$$(\text{BOD})_{u, \text{mix}} = \frac{8 \times 100 + 20 \times 6}{8 + 20} = 32.86 \text{ mg/l}$$

Also, given BOD remaining in the river = 5 mg/l

$$I_t = I_0 e^{-kt}$$

$$5 = 32.86 e^{-0.252 \times t}$$

$$t = 7.47 \text{ days}$$

 \therefore Distance after which BOD remaining (= 5 mg/l)

$$S = Vt$$

$$= \frac{0.35 \times 7.47 \times 86400}{1000} \text{ km} = 225.94 \text{ km}$$

