

Io	Component	Concentration (mg/L)	Eq. Weight (mg/meg)	Concentration (meg/L)
	Ca ²⁺	94	20	4.7
	Mg ²⁺	24	12.2	1.97
	Na ⁺	14	23	0.61
	SO ₄ ²⁻	267	48	1.40
	Cl ⁻	24	35.5	0.68

Σ cations = 4.7 + 1.97 + 0.61 = 7.28
 Σ anions = 1.40 + 0.68 = 2.08

$$\text{Difference} = \frac{\Sigma \text{cations} - \Sigma \text{anions}}{\Sigma \text{cations} + \Sigma \text{anions}} \times 100\%$$

$$= \frac{7.28 - 2.08}{7.28 + 2.08} \times 100\%$$

$$= 55.6\% \text{ (Not acceptable)}$$

∴ Hence the analysis is not complete. For Σ anions 0-3.0 meg/L, the acceptable difference is ±0.2%

(ii) To balance Σ cations & Σ anions, the amount of HCO₃⁻ needed = 7.28 - 2.08 = 5.2 meg/L
 [HCO₃⁻] = 5.2 × 61 = 317.2 mg/L

Ca ²⁺	4.7	Mg ²⁺	1.97	Na ⁺	0.61
HCO ₃ ⁻	5.20	SO ₄ ²⁻	1.40	Cl ⁻	0.68

Ca(HCO₃)₂ = 4.7 meg/L MgSO₄ = 1.4 meg/L NaCl = 0.61 meg/L
 Mg(HCO₃)₂ = 0.5 meg/L MgCl₂ = 0.07 meg/L

(iv) Carbonate hardness = 317.2 × $\frac{50}{61}$ = 260 mg/L as CaCO₃
 Total hardness = (4.7 + 1.97) × 50 = 333.5 mg/L as CaCO₃
 Non-carbonate hardness = Total hardness - Carbonate hardness
 = 333.5 - 260 = 73.5 mg/L as CaCO₃

- (b) Provide service storage to meet fluctuating demand (i.e. equalizing storage)
- For fire fighting purposes
 - To meet emergency requirements (supply system is out of service, pump failure etc)
 - To equalize operating pressures
- Allow smaller water treatment plant to be built

Yes, U Can!

(ii) Total demand : $10,776 \text{ m}^3/\text{day}$

Uniform pumping rate : $\frac{10,776}{24} = 449 \text{ m}^3/\text{hr}$

Time	Demand (m^3)	Pump (m^3)	Excess Demand (m^3)	Excess Supply (m^3)
12-2 am	416	898		482
2-4 am	296	898		602
4-6 am	560	898		338
6-8 am	1056	898	158	
8-10 am	1112	898	214	
10-12 noon	1060	898	162	
12-2 pm	1032	898	134	
2-4 pm	1112	898	214	
4-6 pm	1392	898	494	
6-8 pm	1440	898	542	
8-10 pm	800	898		98
10-12 midnight	500	898		398
			1918	1918

Pumping rate : $449 \text{ m}^3/\text{hr}$

Equalising storage : 1918 m^3

(iii) Pumping rate for 12 hrs : $\frac{10776}{12} = 898 \text{ m}^3/\text{hr}$

Time	Demand (m^3)	Pump (m^3)	Excess Demand (m^3)	Excess Supply (m^3)
12-2 am	416	1796		1380
2-4 am	296	1796		1500
4-6 am	560	1796		1236
6-8 am	1056	1796		740
8-10 am	1112		1112	
10-12 noon	1060		1060	
12-2 pm	1032		1032	
2-4 pm	1112		1112	
4-6 pm	1392		1392	
6-8 pm	1440		1440	
8-10 pm	800	1796		996
10-12 midnight	500	1796		1296
			7148	7148

Equalising storage : 7148 m^3

Yes, U can!

2a Colloids can be destabilized by charge neutralization. Using positively charged ions (Na^+ , Mg^{2+} , Al^{3+}) to neutralize the colloidal negative charge and this destabilize them. There are 2 possible mechanisms:

- Double layer compression - coagulant ions compress the double layer
- Charge neutralization - counter ions adsorbed onto surface of colloidal particles and neutralize the repulsive charges

The objective of flocculation is to enhance the formation of flocs in order to increase the particle size to settle down.

b For anthracite: $Re = \frac{\rho v d}{\mu} = \frac{0.9 \times 0.001 \times 1.736 \times 10^{-3}}{10^{-6}} = 1.56 > 1$

$$C_D = \frac{24}{Re} + \frac{3}{\sqrt{Re}} + 0.34 = 18.10$$

$$h = \frac{1.067 \times 18.10 \times (1.736 \times 10^{-3})^2}{L \times 0.9 \times 9.81 \times 0.001 \times 0.45^4} = 0.161$$

$$h = 80.4 \text{ mm}$$

For sand: $Re = \frac{0.75 \times 0.5 \times 10^{-3} \times 1.736 \times 10^{-3}}{10^{-6}} = 0.651 < 1$

$$C_D = \frac{24}{Re} = 36.87$$

$$h = \frac{1.067 \times 36.87 \times (1.736 \times 10^{-3})^2}{L \times 0.75 \times 9.81 \times 0.5 \times 10^{-3} \times 0.4^4} = 1.26$$

$$h = 378 \text{ mm}$$

$$\text{Total head loss} = 80.4 + 378 = 458.4 \text{ mm}$$

(iii) $f_e = \frac{1-f}{1-f_e} = 1.4$

$$f = \frac{0.45 \times 5 + 0.4 \times 3}{5+3} = 0.43$$

$$f_e = 0.59$$

$$V_b = V_s f_e^{0.5} = 0.12 \times 0.59^{0.5} = 0.011 \text{ m/s}$$

(iii) $d_2^* = d_1 \left(\frac{S_{s1} - 1}{S_{s2} - 1} \right)^{2/3}$
 $= 0.0005 \left(\frac{2.65 - 1}{1.95 - 1} \right)^{2/3}$

$= 1.04 \times 10^{-3} \rightarrow d$; intermixing during backwash is unlikely to occur.

Yes, U Can!

$Q = 90,000 \text{ m}^3/\text{d}$
 $OR = 35 \text{ m}^3/\text{m}^2 \cdot \text{d}$
 $l = 3 \text{ hr}$
 $LR = 250 \text{ m}^3/\text{m}^2 \cdot \text{d}$

$L = 2.5 : 1$
 B

Q per basin : $22,500 \text{ m}^3/\text{d}$

$V = Q \times t$

$22500 \times 3 = 2812.5 \text{ m}^3$
 24

$A = \frac{Q}{OR} = \frac{22500}{35} = 642.86 \text{ m}^2$
 $OR = 35$

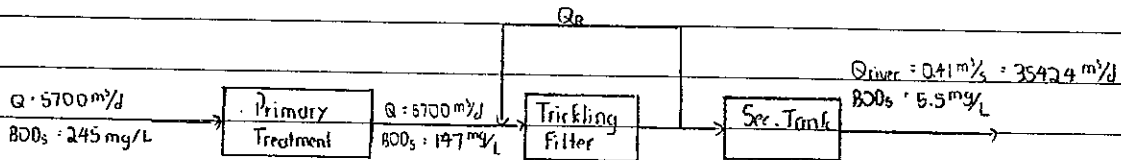
$h = \frac{V}{A} = 4.375 \text{ m}$

$A = B \times L = 642.86$

$B \times 2.5B = 642.86$

$B = 16 \text{ m} ; L = 40 \text{ m}$

30 (ii)



BOD downstream of discharge point to be less than 9 mg/L , assume BOD effluent = x

$9(5700 + 35424) = 5700x + 35424(5.5)$

$x = 30.75 \text{ mg/L}$

$E = \frac{147 - 30.75}{147} \times 100\%$

$= 79.1\%$

Yes, U Can!

(ii) $R = 2.1$

$$F = \frac{1+2.1}{(1+0.1 \times 2.1)^2} = 3.12$$

$$W = Q \times 800_s = 147 \times 10^6 \text{ kg/L} \times 5.7 \times 10^6 \text{ L/d} \\ = 837.9 \text{ kg/d}$$

$$E = \frac{100}{1 + 0.448 \sqrt{\frac{W}{VF}}} = 79.1$$

$$\frac{100}{1 + 0.448 \sqrt{\frac{837.9}{V \times 2.1}}} = 79.1$$

$$V = 1136 \text{ m}^3$$

$$\frac{1}{4} \pi d^2 h = 1136$$

$$\frac{1}{4} \pi d^2 (2.2) = 1136$$

$$d = 25.6 \text{ m}$$

(iii) $A_s = \frac{1}{4} \pi (25.6)^2 = 514.7 \text{ m}^2$

$$\text{Hydraulic Loading} = \frac{Q + Q_R}{A_s} = \frac{Q + RQ}{A_s} \\ = \frac{(1+2.1) \times 5700}{514.7} \\ = 34.3 \text{ m}^3/\text{m}^2 \cdot \text{d}$$

b $Q = 2000 \text{ m}^3/\text{d}$

$$X = 0.75 \times 3500 = 2625 \text{ mg/L MLVSS}$$

$$S_0 = 250 \text{ mg/L}$$

(i) $F = 0.4 = \frac{250 \times 2000}{M}$

$$M = V_r \times 2625$$

$$V_r = 476 \text{ m}^3$$

$$\text{VLR} = \frac{Q \times S_0}{V_r} = \frac{2000 \times 250 \times 10^{-3}}{476}$$

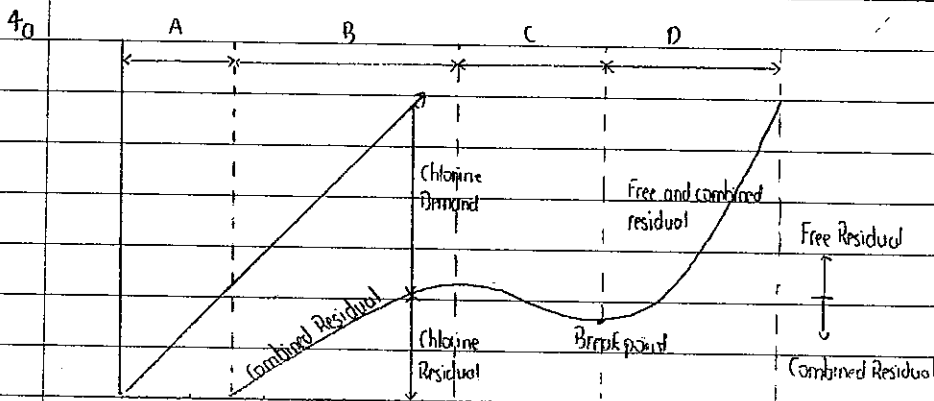
$$= 1.05 \text{ kg BOD}/\text{m}^3 \cdot \text{d}$$

Yes, U can!

(ii) $HRT = \frac{V_r}{Q} = \frac{476}{2000} \times 24 = 5.71 \text{ hr}$

$SRT = \frac{V_r \times X}{Q_e X_e + Q_w X_r} = \frac{476 \times 3.5 \times 15\%}{40 \times 1000 \times 0.6\%} = 5.2 \text{ days}$

Assume $X_e \approx 0$



A: Destruction of chlorine residual by reducing compounds

B: Formation of chloro organic compounds and chloramines

C: Destruction of chloramines and chloro-organic compounds

D: Formation of free chlorine and presence of chloro-organic compounds not destroyed

Break point implies the addition of enough chlorine to completely oxidize NH_3 , thus producing free chlorine residual. Free chlorine more effective than chloramine but can react with natural organic matter (NOM) in raw water

to produce trihalomethanes (THM)

b) Pre-chlorination inactivates microorganisms and reduces tastes and odour by oxidizing organic materials

Post-chlorination is a process where chlorine added for disinfection as well as preventing biological growth in pipes and storage tanks

Chlorination of water containing humic organic substances produces toxic chlorinated by-products such as:

Volatile hydrophobic compounds: Trihalomethanes (THM)

Non-volatile hydrophilic compounds: Chlorinated and non-chlorinated aromatic and aliphatic compounds

Yes, U Can!

$$c \quad Q = 400 \times 15000 = 6000 \text{ m}^3/\text{d}$$

$$\text{Weight of solid: } W_s = 6000 \times 250 \times 10^3 \times 0.15 = 975 \text{ kg/d}$$

(i) Assume $W_s = 1$ for the solids in the sludge

$$\frac{W_s}{\rho_s} = \frac{W_f}{\rho_f} + \frac{W_v}{\rho_v}$$

$$1 = 0.4 + 0.6$$

$$S_s = S_f + S_v$$

$$1 = 0.4 + 0.6$$

$$S_s = 2.5 + 0.9$$

$$S_s = 1.210$$

Assume $W_{s1} = 1$

$$\frac{W_{s1}}{S_{s1} \cdot \rho_w} = \frac{W_s}{S_s \cdot \rho_w} + \frac{W_w}{\rho_w}$$

$$1 = 0.045 + 0.955$$

$$S_{s1} = 1.21 + 1$$

$$S_{s1} = 1.008$$

$$V_{sL} = \frac{W_s}{S_{sL} \cdot \rho_w \cdot \rho_s} = \frac{975}{1.008 \times 1000 \times 4.5\%} = 21.50 \text{ m}^3/\text{d}$$

(ii) $W_{s1} = W_{s2}$

$$P_1 V_{sL1} \rho_{sL1} = P_2 V_{sL2} \rho_{sL2}$$

Assume $\rho_{sL1} = \rho_{sL2} = \rho_w$

$$P_1 V_{sL1} = P_2 V_{sL2}$$

$$4.5\% \times 21.50 = P_2 \times 21.5 (1 - 40\%)$$

$$P_2 = 7.5\%$$

Assume $\rho_s = 10^6 \text{ mg/L}$

$$\text{Solid content} = 7.5\% \times 10^6 = 75000 \text{ mg/L}$$

