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<u>EN2003</u>

21-22 S2

Q1(a)

$$Z_1 + E_P = Z_2 + E_3 + H_{L,1} + 10$$

$$Z_3 = Z_2 + E_3 + H_{L,3} + 5$$

Q1(b)

$$P = \rho g h$$

400 kPa → 40.77m head

$$10 + 100 = 20 + 40.77 + H_{L,1} + 10$$

$$H_{L,1} = 39.23\ m$$

$$39.23 = f \frac{L}{d} \frac{{\text{v}_1}^2}{2g}$$

$$\text{v}_1 = 1.52\ m/s$$

$$\boldsymbol{Q_1 = \text{v}A = 0.43 m^3/s}$$

$$70 = 20 + 40.77 + H_{L,3} + 5$$

$$H_{L,3} = 4.23\ m$$

$$4.23 = f \frac{L}{d} \frac{{\text{v}_3}^2}{2g}$$

$$\text{v}_3 = 0.706\ m/s$$

$$\boldsymbol{Q_3 = 0.2\ m^3/s}$$

$$\boldsymbol{Q_D = 0.2 + 0.43 = 0.63 m^3/s}$$

Q1(c)

New flow = $120\% \times 0.63 = 0.756m^3/s$

Pump has to provide $Q_1 = (0.756 - 0.63) + 0.43 = 0.556m^3/s$

$v_1 = 1.966\ m/s$

$$H_{L,1} = f\frac{L}{d}\frac{{v_1}^2}{2g} = 65.7\ m$$

$$10 + E_p = 20 + 40.77 + 65.7 + 10$$

$$\boldsymbol{E_p = 126.5\ m}$$

Q1(d)

$$10 = K_L\frac{1.52^2}{2g}$$

$$\boldsymbol{K_L = 85}$$

Q2(a)(i)

For tapered flocculation, higher initial G allows for formation of denser flocs, while subsequent tanks with lower G allows for formation of larger flocs

Q2(a)(ii)

$$\frac{dN}{dt} = -\frac{4}{\pi}G\alpha\Omega N_E$$

$$\frac{N_E - N_I}{t} = -\frac{4}{\pi}G\alpha\Omega N_E$$

Rearranging,

$$\frac{N_E}{N_I} = \frac{1}{1 + \frac{4}{\pi}G\alpha\Omega N_E}$$

Ω remains constant throughout the process

$$N_E V_{P,E} = N_I V_{P,I}$$

$$N_E\frac{d_E^3}{6}\pi = N_I\frac{d_I^3}{6}\pi$$

$$N_E \frac{(2d_I)^3}{6}\pi = N_I \frac{d_I^3}{6}\pi$$

$$\boldsymbol{\frac{N_E}{N_I} = \frac{d_I^3}{6} \div \frac{4d_I^3}{3} = \frac{1}{8}}$$

Q2(a)(iii)

$$0 = QN_I - QN_E + \frac{dN}{dt}V$$

Q2(a)(iv)

Minutes for coagulation, 30 minutes to an hour for flocculation. Flocculation takes more time, as process has to be more gentle and thus slower in order to not destroy flocs formed. For coagulation, focus is not on forming larger flocs yet, and thus process is more rapid to ensure faster and better mixing of chemicals for faster reaction.

Flocculation also requires longer time to allow for more collisions to occur between particles, allowing for formation of larger flocs.

Q2(b)(i)

$$Q = \frac{32000}{24\times60\times60} = 0.37\ m^3/s$$

$$V_O = SOR = \frac{Q}{A} = \frac{0.37}{400\times2} = 0.0004625\ m/s$$

$$V_s = \frac{g(\rho_s-\rho)d^2}{18\mu} = 0.00122 \text{ m/s} > V_o$$

Removal efficiency is 100%

Q2(b)(ii)

In one tank,

$$Q = \frac{0.37}{2} = 0.185\frac{m^3}{s}$$

$$V = \frac{0.185}{10\times4} = 0.004625\ m/s < 0.1\ m/s$$

Flow velocity is acceptable

Q2(c)

Sand filter polishes water after sedimentation step, removing flocs, solids and microorganisms that failed to settle to the bottom during the sedimentation stage.

Q3(a)(i)

Coagulation has to occur at pH 5.2 to 8.8 to be effective. At high pH, only negatively charged aluminium complexes will form, these complexes do not neutralise the negative charge of colloids, and no coagulation occurs. At low pH, only Al^{3+} and positively charged aluminium complexes form, no precipitates form. While charge neutralisation occurs, enmeshment of particles by precipitates does not occur. Only at pH 5.2 to 8.8 will both charge neutralisation and enmeshment of particles occur.

Q3(a)(ii)

$1\,mg/L$ of $Al^{3+} \rightarrow 0.000037\,mol\;of\;Al^{3+} \rightarrow 0.00011\,mol\;\;HCO_3^-$

$$= 6.78\,mg/L\;\;HCO_3^-$$

$$EW\;HCO_3^- = \frac{61}{1} = 61$$

$$EW\;CaCO_3 = \frac{100}{2} = 50$$

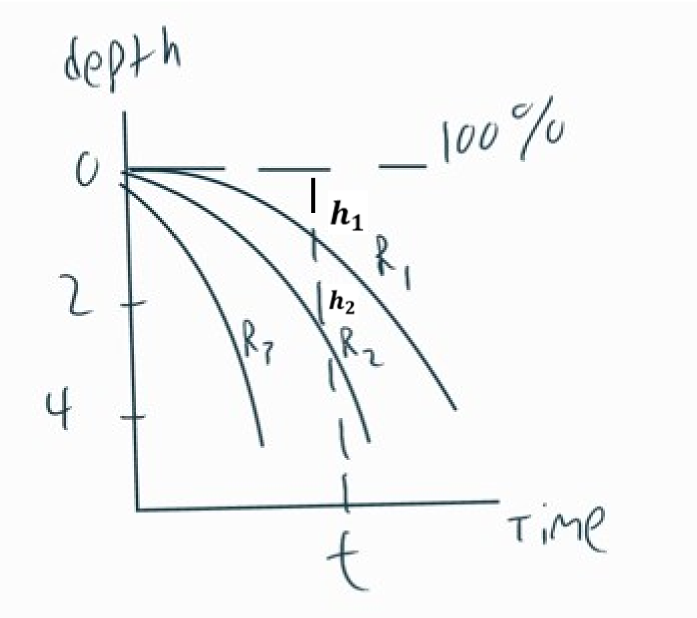
Alkalinity consumed = $\frac{50}{61} \times 6.78 = 5.56\,mg/L$ as $CaCO_3$

Q3(a)(iii)

Lime or soda would likely need to be added for (B). Lime and soda would likely not be needed for (C). For A and D, we would need to study if alkalinity present in water is enough to get rid of turbidity present via coagulation process. If alkalinity is found to be insufficient, then lime or soda has to be added.

Q3(b)

Using a settling column with sampling point at varied depths, collect data on concentration of particles in sample to obtain % removal at the various depths at various time. Plot a graph of depth against time, and draw curves connecting points with equal % removal



Draw a straight vertical line at time (t) that you want to study. R represent the %removal that each line represents.

Find the halfway point between two curves, label the depth of that point as h.

% removal can then be estimated using the below formula :

$$\%R = \frac{h_1}{h_0}(100 - R_1) + \frac{h_2}{h_0}(R_1 - R_2) + R_2$$

Q3(c)

$$\frac{1}{q_e} = \frac{1 + aC_e}{q_{max} aC_e}$$

$$\frac{1}{q_e} = \frac{1}{q_{max} aC_e} + \frac{aC_e}{q_{max} aC_e}$$

$$\frac{1}{q_e} = \frac{1}{q_{max} a} \frac{1}{C_e} + \frac{1}{q_{max}}$$

Plot a graph of $\frac{1}{q_e}$ against $\frac{1}{C_e}$, line should be linear if Langmuir isotherm is equation is suitable. Gradient of the line will give $\frac{1}{q_{max} a}$ while y-intercept will give $\frac{1}{q_{max}}$

Q4(a)

Conc NaCl = $\frac{33}{23+35.5} = 0.564 \text{ mol/L}$

Conc Na = Conc Cl = 0.564 mol/L

$\pi = CRT = (0.564 + 0.564) \times 0.082 \times (273 + 27) = 27.6\ atm$

Q4(b)

$Q = \frac{4500}{24 \times 60 \times 60} = 0.0521\ m^3/s$

$V_s = \frac{Q}{A} = \frac{0.0521}{8 \times 5} 0.0013\ m/s$

$$Re = \frac{\phi V_s d}{v} = 0.425$$

$f' = 150 \frac{1-e}{Re} = 194$

$$h_f = \frac{f'}{\phi} \frac{1-e}{e^3} \frac{L}{d} \frac{V_s^2}{g} = 0.237\ m$$

Q4(c)

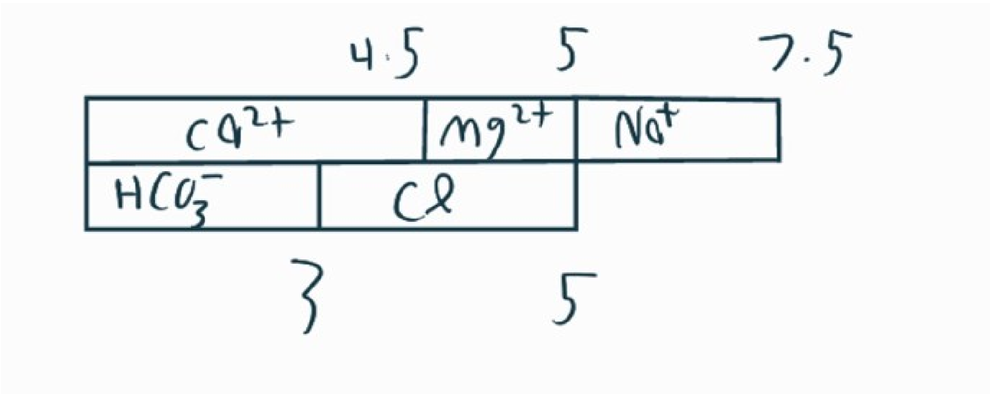
Adding chlorine to water till inorganics and organics are reacted away, including reactions with chloramine, so that past the break point, all Cl added is free chlorine.

Provides free chlorine which is a strong disinfectant to inactivate microbes, while also allowing for the presence of combined chlorine which acts as residue disinfectant to prevent regrowth of microbes in the distribution system. Also removes organics and inorganics which may cause taste and odour problems.

Q4(d)(i)

Ion	Conc (mg/L)	EW	Conc (meq/L)
Ca^{2+}	90	20	4.5
Mg^{2+}	6	12	0.5
Na^{+}	57.5	23	2.5
HCO_3^{-}	183	61	3
Cl^{-}	71	35.5	2

Note : conc in meq/L = $\frac{conc\ of\ ion}{EW\ ion}$



Q4(d)(ii)

TH = 5 meq/L

CH = 3 meq/L

NCH = 5 – 3 = 2 meq/L