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EN2003 2018 - 2019 Sem 2

1ai)

Draft (%)	Cumulative Defficiency (%)	Defficiency (%)	Inflow (%)
3	3	3	0
2	5	2	0
3	8	3	0
4	12	4	0
9	1	-11	20
13	-6	-7	20
18	-8	-2	20
13	-15	-7	20
12	-23	-8	20
10	-13	10	0
9	-4	9	0
4	0	4	0

Maximum cumulative excess = operational volume
= 23% of tank
= 80 000 x 23%
= 18400 m^3

Maximum cumulative deficit = equalizing volume
= 12% of tank
= 9600 m^3

1aii) Volume pumped every 2 hours = 80 000 x 20%
= 16000 m^3

∴ Pumping rate = 8000 m^3/hr

1b) Diameter = 800mm = 0.80m

$$Q = 0.278\ C\ D^{2.63} S^{0.54}$$

$$Q = 0.278\ C\ D^{2.63} \left[\frac{h_L}{L}\right]^{0.54}$$

$$Q = 0.278\ C\ D^{2.63} \left[h_L\right]^{0.54} \left[\frac{1}{L}\right]^{0.54}$$

$$\left[h_L\right]^{0.54} = \frac{1}{0.278\, C D^{2.63} \left[\frac{1}{L}\right]^{0.54}}\ Q$$

$$h_L = \frac{L}{0.0934\, C^{1.85} D^{4.87}}\ Q^{1.85}$$

$$= \frac{12000}{0.0934\,(120)^{1.85}\,(0.80)^{4.87}}\ (1.6667)^{1.85}$$

$$= 139.55\text{m}$$

$$h_{LM} = 139.55 \times 15\%$$

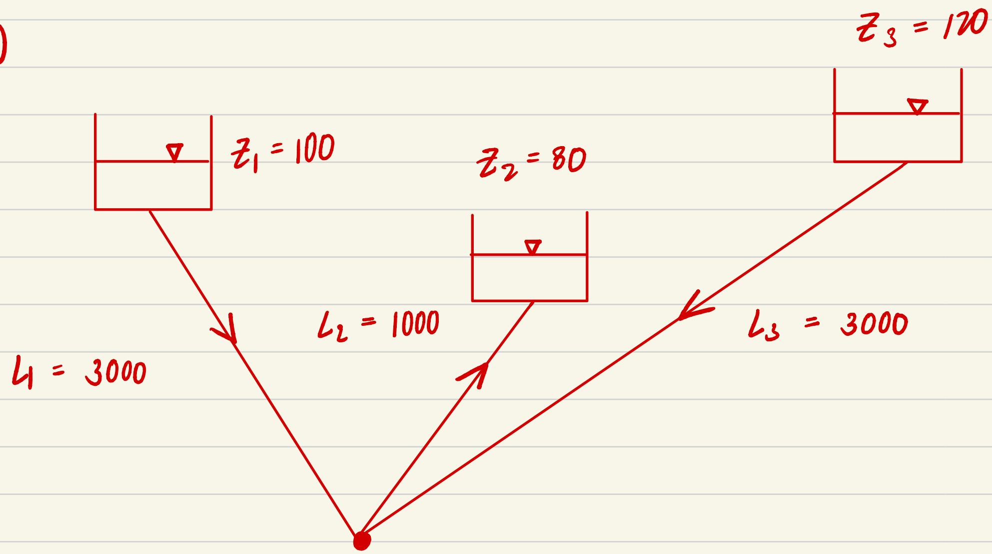
$$= 20.933\text{ m}$$

$\therefore$ Pump head needed $= 40 + 139.55 + 20.933$

$= 200.48$ m

≈ 200 m

1c)



$$Q_1 - Q_2 + Q_3 - Q_J = 0$$

	Pipe 1	pipe 2	pipe 3
L	3000	1000	3000
D	0.30	0.30	0.30
C	100	100	100
K	2226.5	742.15	2226.5

Applying energy equation between R_1 and R_2,

$$2226.5\,Q_1^{1.85} + 742.15\,Q_2^{1.85} = 100 - 80$$

$$2226.5\,Q_1^{1.85} = 20 - 742.15\,Q_2^{1.85}$$

$$Q_1 = \left[\frac{20 - 742.15\,Q_2^{1.85}}{2226.5}\right]^{\frac{1}{1.85}}$$

$$= 0.078295 - 0.55219\,Q_2$$

Applying energy equation between R_2 and R_3

$$2226.5\,Q_3^{1.85} + 742.15\,Q_2^{1.85} = 120 - 80$$

$$2226.5\,Q_3^{1.85} = 40 - 742.15\,Q_2^{1.85}$$

$$Q_3 = \left[\frac{40 - 742.15\,Q_2^{1.85}}{2226.5}\right]^{\frac{1}{1.85}}$$

$$= 0.11388 - 0.55219\,Q_2$$

$$F(Q_2) = Q_1 - Q_2 + Q_3 - Q_J$$

$$= (0.078295 - 0.55219\,Q_2) - Q_2 + 0.11388 - 0.55219\,Q_2 - Q_J$$

$$= -0.47390 - 2.10438\,Q_2 - Q_J$$

2ai)

$$\Omega_{coagulated} = \frac{\pi d_0^3 N_0}{6}$$

$$\Omega_1 = \frac{\pi d_1^3 N_1}{6}$$

$$\Omega_2 = \frac{\pi d_2^3 N_2}{6}$$

$\Omega_{coagulated} = \Omega_1 = \Omega_2$ since total volume of flocs and total volume of water remains the same.

2aii)

2aiii) $$\frac{N_E}{N_1} = \left[\frac{1}{1+\frac{4}{\pi}G_1\alpha\Omega t_1}\right]\left[\frac{1}{1+\frac{4}{\pi}G_1\alpha\Omega t_2}\right]$$

$$\therefore \text{Overall Flocculation Efficiency} = 1 - \left[\frac{1}{1+\frac{4}{\pi}G_1\alpha\Omega t_1}\right]\left[\frac{1}{1+\frac{4}{\pi}G_1\alpha\Omega t_2}\right]$$

2aiv) Longer hydraulic retention time will lead to higher flocculation efficiency. As seen from equation in (2aiii), larger t value will lead to smaller $\frac{N_E}{N_1}$ value and hence higher overall flocculation efficiency. This is also due to particles requiring sufficient time to have successful collisions.

2b) Flow rate in one basin $= 10\,000 \ m^3/d$
$= 0.11574 \ m^3/s$

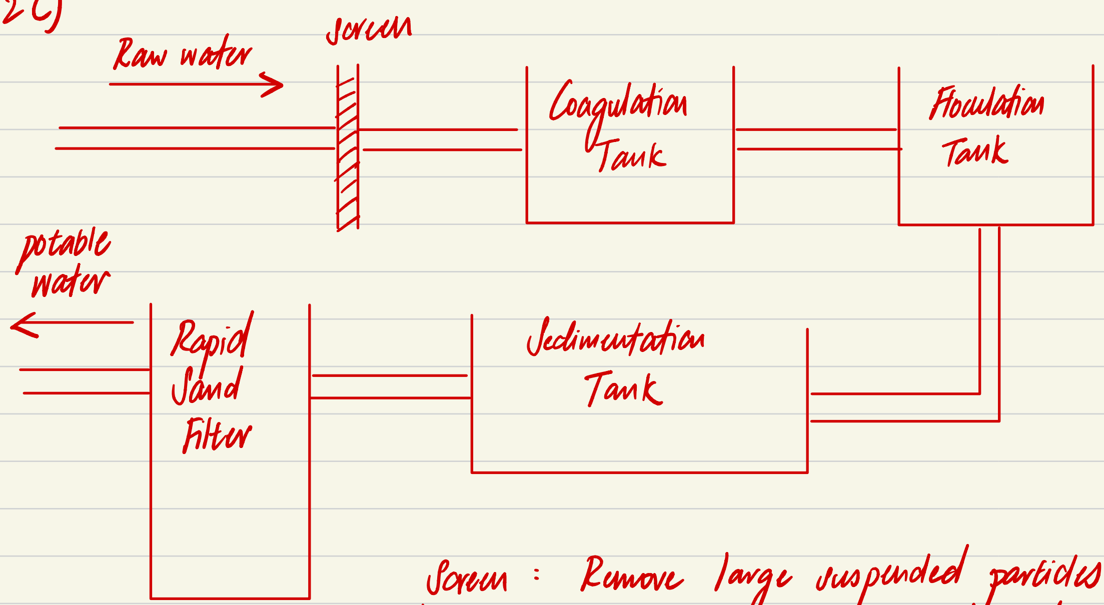
$$\text{Surface overflow rate} = \frac{0.11574}{40 \times 10}$$
$= 0.00028935 \ m/s$

For particle with $d = 100 \times 10^{-6}$ m,

$$V_s = \frac{(9.81)(1050-1000)(100\times10^{-6})^2}{18 \times 0.89 \times 10^{-3}}$$

Since settling velocity > surface overflow rate OR $V_s > V_0$, the 100µm particle will be completely removed.

2c)



Screen : Remove large suspended particles

Coagulation tank : Destabilize negatively charged colloidal particles with coagulant

Flocculation tank : Allow coagulated particles to stick together to form larger, more settlelable flocs

Sedimentation tank : Allow large flocs to settle to the bottom and be removed.

Filtration unit : Remove smaller flocs and colloidal particles that may have escaped sedimentation tank.

3ai) Type of coagulant
Dosage of coagulant
pH of water
Temperature of water
Mixing Power

3aii) $Al_2(SO_4)_3 + 6HCO_3^- \longrightarrow 2Al(OH)_3 + 6CO_2 + 3SO_4^{2-}$

MW of $Al_2(SO_4)_3 = (27 \times 2) + (32 \times 3) + (12 \times 16)$
$= 342$

EW of $Al_2(SO_4)_3 = 114$

MW of $HCO_3^- = 1 + 12 + (16 \times 3)$
$= 61$

EW of $HCO_3^- = 61$

1 mg/L $Al_2(SO_4)_3$ = 0.0029240 mmol/L

From eqn, 1 mol $Al_2(SO_4)_3$ reacts with 6 mol HCO_3^-

0.0029240 mmol $Al_2(SO_4)_3$ reacts with 0.017544 mmol HCO_3^-

Water alkalinity consumed by Al^{3+} $= \frac{50}{114} \times (0.017544)(61)$
$= 0.46938$ mg/L as $CaCO_3$

$FeCl_3 + 3HCO_3^- \longrightarrow Fe(OH)_3 + 3CO_2 + 3Cl^-$

MW of $FeCl_3 = 56 + (35.5 \times 3)$
$= 162.5$

EW of $FeCl_3 = 54.167$

1 mg/L $FeCl_3$ = 0.0061538 mmol/L

From equation 1 mol $FeCl_3$ reacts with 3 mol HCO_3^-

0.0061538 mmol $FeCl_3$ reacts with 0.018462 mmol HCO_3^-

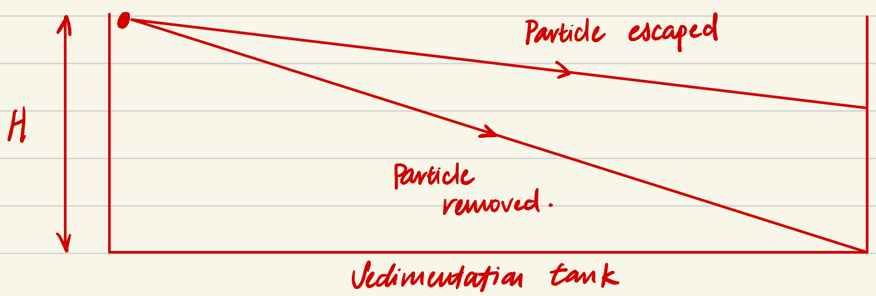
$$\text{Water alkalinity consumed} = \frac{50}{54.167} \times (0.018462)(61)$$

$$= 1.0395 \text{ mg/L as } CaCO_3$$

3aiii) $FeCl_3$ consumes more water alkalinity than $Al_2(SO_4)_3$

3aiv) Lime or soda needs to be added to raise pH during water coagulation with Aluminium sulphate when pH drops below 5.2. When pH falls below 5.2, Al^{3+} forms positively charged complexes causing $Al(OH)_3$ to not precipitate. This thus reduces enmeshment capabilities of the precipitate and reduces overall coagulation efficiency.

3b)



For particle to be removed, particle must fall distance of H within detention time, t.

$$V_s \geq \frac{H}{t} \quad \text{and} \quad t = \frac{V}{Q}$$

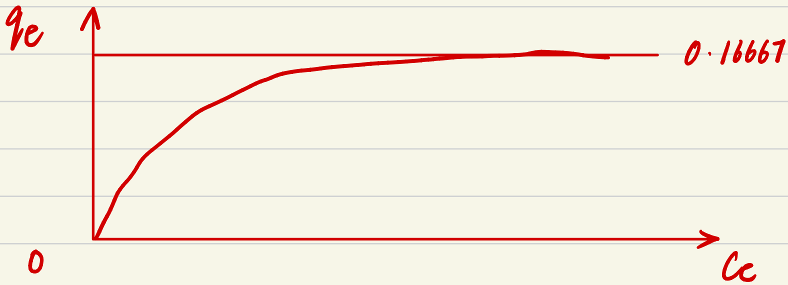
$$V_s \geq \frac{H}{H \times W \times L / Q} = \frac{Q}{A} \text{ OR } V_0$$

∴ Removal Efficiency is dependent on V_0 OR surface overflow rate

$$\text{Removal Efficiency}, \; X_r = \frac{V_s}{V_0} \times 100\%$$

3c) Initial COD conc. = 180 mg/L

No.	Mass of GAC	Final COD (mg/200ml)	q_e
1	800	1.0	0.07375
2	610	1.5	0.08806
3	510	2.0	0.11373
4	400	3.0	0.1425
5	300	10.0	0.16667
6	240	20.0	0.16667
7	0	60.0	



When q_e is plotted against C_e, it can be observed that q_e reaches an asymptote of 0.16667 which determines that Langmuir isotherm is suitable.

4a) MW of glucose $= (12 \times 6) + 12 + (16 \times 6)$
$= 180$

molar conc. of glucose $= 0.01$ mol/L

MW of NaCl $= 23 + 35.5$
$= 58.5$

molar conc. of NaCl $= 0.4$ mol/L

$NaCl \longrightarrow Na^+ + Cl^-$

MW of $MgCl_2$ $= 24 + (35.5 \times 2)$
$= 95$

molar conc. of $MgCl_2$ $= 0.02$ mol/L

$MgCl_2 \longrightarrow Mg^{2+} + 2Cl^-$

Osmotic Pressure $= CRT$
$= (0.01 + 0.8 + 0.06)(0.082)(273+27)$
$= 21.402$ atm
≈ 21.4 atm

4bi)

$$Re = \frac{\phi V_s d}{\nu}$$

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

$$= 150 - \frac{(1-e)(\nu)}{\phi V_s d}$$

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

$$= \left[\frac{150}{\phi} - \frac{(1-e)(\nu)}{\phi^2 V_s d}\right] \frac{1-e}{e^3} \frac{L}{d} \frac{V_s^2}{g}$$

$$0.80 = \left[\frac{150}{0.85} - \frac{(1-0.4)(1.3\times10^{-6})}{(0.85)^2 V_s (0.6\times10^{-3})}\right] \frac{1-0.4}{(0.4)^3} \frac{0.5}{(0.6\times10^{-3})} \frac{V_s^2}{9.81}$$

$$0.80 = \left[176.47 - \frac{13}{7225V_s}\right]\left[\frac{75}{8}\right]\left[\frac{2500}{3}\right]\left[\frac{V_s^2}{9.81}\right]$$

$$\frac{8}{78125} = \left[176.47 - \frac{13}{7225V_s}\right]\left[\frac{V_s^2}{9.81}\right]$$

$$= 17.989 V_s^2 - \frac{52}{283509} V_s$$

Solving for V_s, $V_s = 0.0023910$ m/s

≈ 0.00239 m/s

4bii) Flowrate for one filter = $0.0023910 \times 5 \times 8$

$= 0.09564 \ m^3/s$

$\therefore$ Allowable daily productivity $= 0.09564 \times 10 \times 60 \times 60 \times 24$

$\approx 82633 \ m^3$

4ci) $Cl_2 + H_2O \longrightarrow H^+ + Cl^- + HOCl$

$HOCl \longrightarrow H^+ + OCl^-$

Chlorine applied as gaseous form into water to form hypochlorous acid which may further dissociate into H^+ and hypochlorite ion. Hypochlorous acid 30 times more powerful that hypochlorite ion as disinfectant and favours low pH.

Disinfectants may also be applied as solid forms

Calcium hypochlorite : $Ca(OCl)_2 \longrightarrow Ca^{2+} + 2OCl^-$

Sodium hypochlorite : $Na(OCl) \longrightarrow Na^+ + OCl^-$

4cii) Disinfectants may react with dissolved organic matter to form disinfection by-products such as Halo acetic acids and tri halo methanes which are carcinogens and mutanogens, dangerous for human consumption.

4d)