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EN3002

23-24_S1

Q1(a)(i)

Soda ash used to increase alkalinity : 30 – 10 = 20 mg/L as $CaCO_3$

1 meq/L = 50 mg/L as $CaCO_3$

EW = MW / Electric charge

meq/L = $\frac{mg/L}{EW}$

EW Na_2CO_3 = 106 / 2 = 53 mg/L

20 mg/L as $CaCO_3$ = 0.4 meq/L = 21.2 mg/L Na_2CO_3

= 21.2 g/m^3 Na_2CO_3

Soda ash used to raise Alk = 21.2 × 1000 = 21200 g /d

=21.2 kg/d

Soda ash for reaction with alum = 53 – 21.2 = 31.8 kg/d

Mol of soda ash reacting with alum = $\frac{31.8\times10^3}{106} = 300\ mol/d$

1 mol of alum reacts with 3 mols of soda ash

Mol of alum = 300 / 3 = 100 mol/day

Mass of alum = 100 × 666 = 66600 g/d = 66.6 kg/d

Q1(a)(ii)

At too low a pH, charge neutralisation occurs due to Al^{3+} and positively charged soluble hydroxide complexes. No precipitates are formed.

At too high a pH, no charge neutralisation occurs and only negatively charged soluble hydroxide complexes are formed.

At the optimal pH of 5.2-8.8, charge neutralisation occurs due to Al^{3+} and positively charged hydroxide complexes. $Al(OH)_3$ precipitates also form, and they capture particles they encounter as they settle, thus coagulation-flocculation is most optimal at this pH range.

Q1(b)

Advantages with recycle :

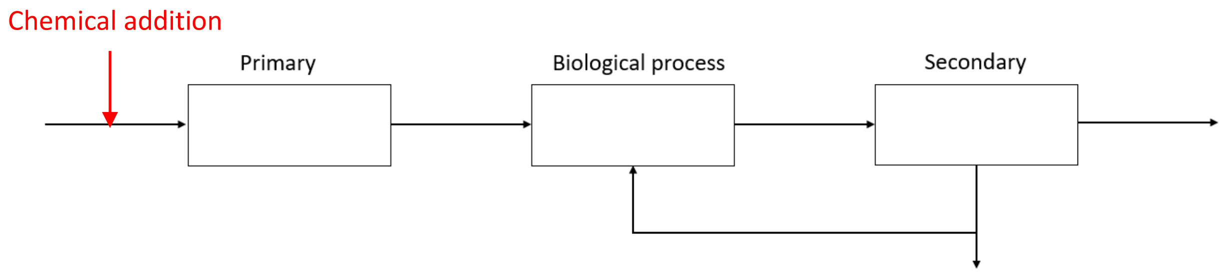
- Prevent incoming solids from being subjected to the shearing action of the pressurised pump
- Larger quantities of air can be introduced since recycle flow can be greater than feed flow

Disadvantages with recycle :

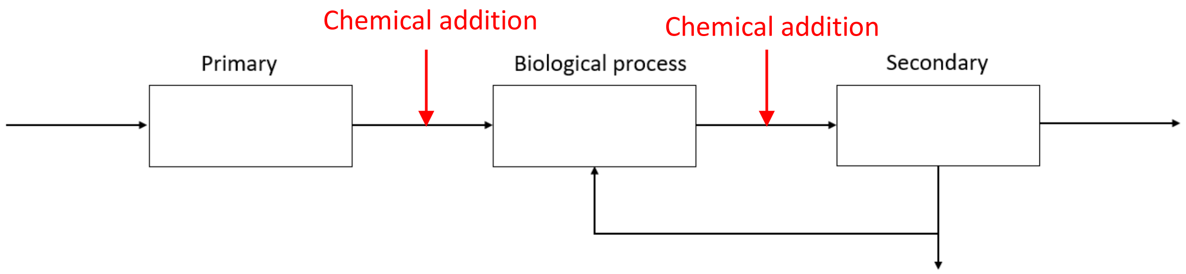
- More costly to build and maintain
- Requires larger land space due to larger size

Q1(c)

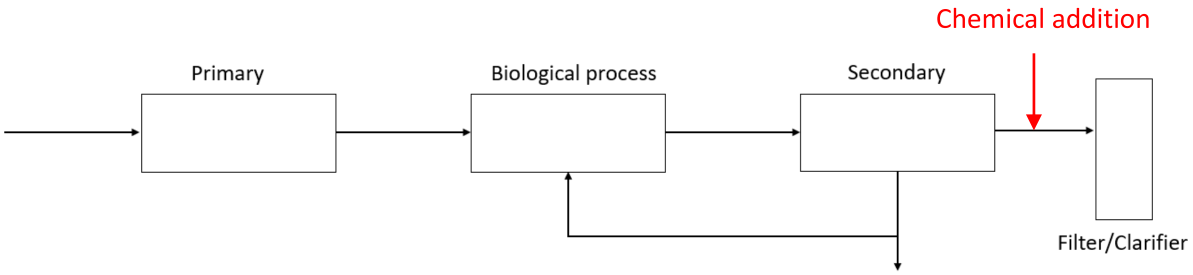
Pre-precipitation process : precipitation and removal of P in primary sedimentation tank



Co-precipitation process : precipitation of phosphate for removal before secondary settling tank, precipitate removal along with waste biological sludge in the secondary settling tank



Post-precipitation process : Chemical dosing to clarified secondary effluent and removal of precipitate by filtration/sedimentation afterwards



Q2(a)(i)

Horizontal velocity = $\frac{200}{10\times3} = 6.67\ m/h$

Time taken to travel 10 m = 10 / 6.67 = 1.5 h

v_s = 0.5 / 1.5 = 0.33 m/h

$v_o = \frac{200}{20\times10} = 1\ m/h$

Fraction removed = 0.33 / 1 = 33 %

Q2(a)(ii)

Same density, double diameter : v_s increase by 4×

$v_s = 0.33 \times 4 = 1.32\ m/h$ > 1.0 m/h

Fraction removed = 100 % since $V_s > V_o$

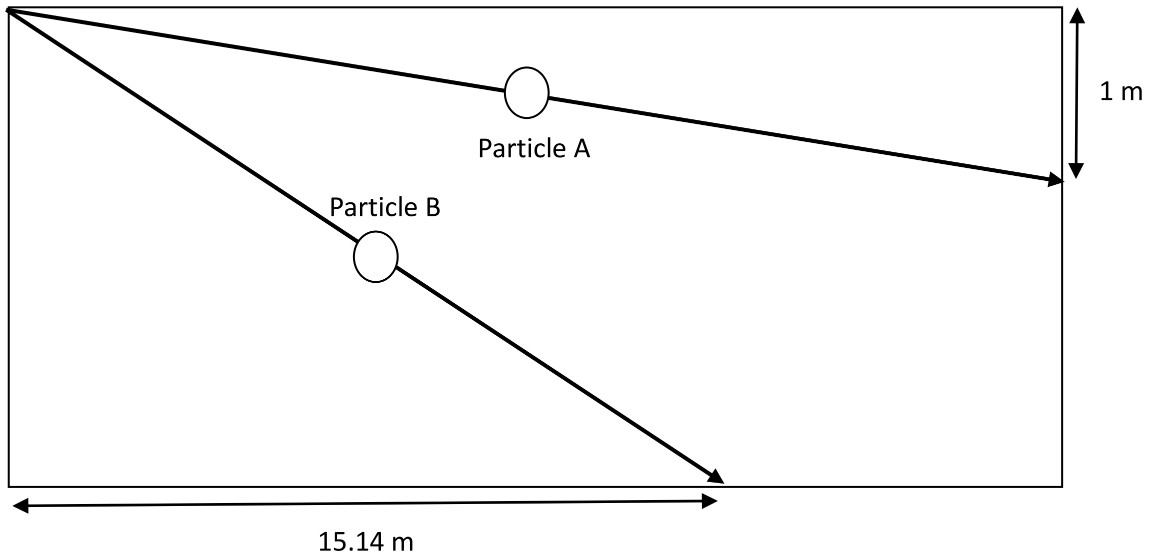
Q2(a)(iii)

Retention time = $\frac{20\times10\times3}{200} = 3\ h$

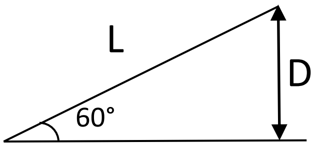
Particle A settles $0.33 \times 3\ \approx 1\ m$ in 3h

Particle B settles after 3 / 1.32 = 2.27 h

Horizontal distance travelled by B = 6.67 × 2.27 = 15.14 m



Q2(b)(i)



$$L = \frac{D}{sin60} = \frac{1}{sin60} = \ 1.155\ m$$

$$A_{screen\ spacing} = \frac{2}{100} \times 41 \times 1.155 = 0.947\ m^2$$

$$V = \frac{1}{0.947} = 1.056\ m/s$$

$$A_{channel} = 1.155 \times (40 \times \frac{1}{100} + 41 \times \frac{2}{100}) = 1.41\ m^2$$

$$v = \frac{1}{1.41} = 0.71\ m/s$$

$$\boldsymbol{H_L = \frac{1}{C}\left(\frac{V^2 - v^2}{2g}\right) = \frac{1}{0.7}\left(\frac{1.056^2 - 0.71^2}{2(9.81)}\right) = 0.0445\ m}$$

Q2(b)(ii)

$$A_{screen\ spacing} = 0.7 \times 0.947 = 0.663\ m^2$$

$$V = \frac{1}{0.663} = 1.51\ m/s$$

$$\boldsymbol{H_L = \frac{1}{C}\left(\frac{V^2 - v^2}{2g}\right) = \frac{1}{0.6}\left(\frac{1.51^2 - 0.71^2}{2(9.81)}\right) = 0.151\ m}$$

Q3(a)

i. Increased SRT, increased amount of activated sludge in the tank, and thus **increased sludge production rate**
ii. Increased SRT means increased amounts of active micro-organisms and thus increased microbial activity, **increasing oxygen consumption rate.**
iii. More micro-organisms present to oxidise COD present in influent, thus **decreasing effluent soluble biodegradable COD concentration**
iv. Increased sludge production, more MLVSS present and thus **increased MLSS concentration**
v. Increased SRT, more activated sludge present in tank, more oxidation of NH_4-N to nitrate, thus **decreasing effluent NH_4-N concentration**

3(b)

$$SVI = \frac{Settled\ sludge\ volume\ (mL/L)}{MLSS\ (mg/L)} \times 1000$$

$$= \frac{(\frac{1000}{2})}{2500} \times 1000 = 200$$

Bulking sludge, very bad settleability. Possibly due to growth of filamentous micro-organisms caused by large SRT or low dissolved oxygen concentration.

3(c)

Influent COD concentration = 8000 mg/L = 8000 g/m^3

Influent COD consumed = 8000 × 2000 × 0.95 = 15,200,000 g/d

= 15200 kg/d

COD used for sulfate reduction = 500 × 2000 × 0.98

= 980,000 g/d

= 980 kg/d

Assuming no COD is used for cell production :

$COD_{methane} = COD_{consumed} - COD_{Sulfate\ reduction}$ =15200 – 980 = 14220 kg/d

At 35 °C : 0.4 m^3 CH_4 /Kg COD

Amount of methane produced : 14220 × 0.4 = 5688 m^3/d

3(d)(i)

Influent COD = 1000 × 4000 = 4,000,000 g/d = 4000 kg/d

Total volume = 4000/5 = 800 m^3

Volume of each reactor = 800/3 = 266.67 m^3

Circular area of 1 reactor = 266.67 / 4 = 66.67 m^2

$$\frac{\pi d^2}{4} = 66.67\ m^2$$

d = 9.21 m

3(d)(ii)

Ignoring COD in new biomass,

$COD_{methane} = COD_{consumed}$ = 0.9 × 4000 = 3600 kg/d

Amount of methane produced : 3600 × 0.4 = 1440 m^3/d

3(d)(iii)

(S_o-S) = 0.9 × 4000 = 3600 mg/L = 3600 g/m^3

$$P_{x,tss} = \frac{YQ(S_o - S)}{(1 + k_d SRT) * 0.85} + \frac{f_d k_d YQ(S_o - S)SRT}{(1 + k_d SRT) * 0.85)} + Q(nbTSS)$$

$$= \frac{0.08(1000)(3600)}{(1 + 0.03 \times 30) * 0.85} + \frac{0.15(0.03)(0.08)(1000)(3600)(30)}{(1 + 0.03 \times 30) * 0.85} + 0$$

$$= 202402\ g/d$$

Effluent TSS concentration = 202402 / 1000 = 202.4 g/m^3

= 202.4 mg/L

Q4(a)

Belt press and centrifuge requires prior chemical conditioning, while drying beds do not.

Belt press and centrifuge have higher dewatering efficiency compared to dying beds.

Belt press and centrifuge have smaller footprint (space requirement) compared to drying beds.

Drying beds are cheaper and simpler to operate compared to belt press and centrifuge.

Belt press is recommended.

Belt press allows for the efficient dewatering of sludge, which is necessary as it greatly reduces the volume of sludge, reducing the cost of transportation over the long distance to the disposal site. Belt press also has a small footprint, allowing it to be build in the city centre where land space is already a limited and valuable resource. Belt press can also run continuously, allowing for the continued dewatering of sludge. Lastly, while it requires significant maintenance to run, it is easier to maintain and run the belt press compared to the centrifuge.

Q4(b)

$$W_1 = 220 \times 5000 \times (1 - 0.35) = 715000\ g/d = 715\ kg/d$$

$$F = \frac{1+R}{\left(1+\frac{R}{10}\right)^2} = \frac{1+2}{\left(1+\frac{2}{10}\right)^2} = 2.08$$

$p_{overall} = \frac{20\times5000}{715000} = 0.14$

$p_1 \times p_2 = 0.14$, $p_1 = p_2 = 0.374$

$E_1 = E_2 = 1 - 0.374 = 0.626$

$$E_1 = \frac{100}{1+0.4432\sqrt{\frac{W_1}{FV_1}}}$$

$$62.6 = \frac{100}{1+0.4432\sqrt{\frac{715}{2.08V_1}}}$$

V_1 = 189.1 m^3

A_1 = 189.1 / 4 = 42.275 m^2

$$A = \frac{\pi d^2}{4}$$

d_1= 7.76 m

W_2 = 715 × 0.374 = 267.41 kg/d

$$E_2 = \frac{100}{1+\frac{0.4432}{1-E_1}\sqrt{\frac{W_2}{FV_2}}}$$

$$62.6 = \frac{100}{1+\frac{0.4432}{1-0.626}\sqrt{\frac{267.41}{2.08V_2}}}$$

V_2 = 505.8 m^3

A_2 = 505.8 / 4 = 126.45 m^2

d_2 = 12.69 m