EN3002

1) (a) $Q = 120\,000\ m^3/d$

$h_L = 0.2m$ ①

Channel depth = 1.5m, width = 2.0m } Area = $3.0m^2$ ⇒ 0.3 area clogged ⇒ $2.1m^2$ clear area (→ C = 0.7)

Bar spacing = 3.0cm

incoming velocity $\dfrac{120\,000\,m^3/d \cdot \frac{1day}{24hrs} \times \frac{24hrs}{3600}secs}{3.0m^2} = \ m/s$

⇓ v

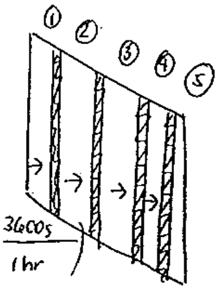
$h_L = \frac{1}{C}\dfrac{(V^2 - v^2)}{2g}$

$h_L \cdot C \cdot 2g + v^2 = V^2$

$V = \sqrt{h_L \cdot C \cdot 2g + v^2}$

↳ velocity passing through. (m/s)

Determine no. of req. bars, width of each bar



Channel area = $3.0m^2$, 30% of flow area clogged.

Q = 120 000 m3/d

approach velocity $\dfrac{120\,000\,m^3/d}{3.0m^2} \Big/ \left(\dfrac{24hrs}{1day} \cdot \dfrac{3600s}{1hr}\right)$

$= 0.4630\ m/s$

Find remaining area based on velocity passing through screen.

$h_L = 0.2m = \frac{1}{C}\left(\dfrac{V^2 - v^2}{2g}\right)$ C = 0.6 (clogged screen)

$\sqrt{h_L \cdot C \cdot 2g + v^2} = V = 1.603\ m/s$

$Q = 120\,000\ m^3/d$ ⇒ area through screen $= \dfrac{120\,000\,m^3/d}{1.603\,m/s} \cdot \dfrac{1day}{24hrs} \cdot \dfrac{1hr}{3600s}$

$= 0.866\ m^2$ clear screen area.

$\dfrac{0.866m^2}{1.5m} = 0.578\ m$ ~~clear~~ flow area.

30% of 0.578 clogged ⇒ $0.7 \times 0.578m = 0.40432\ m$ clear flow area. → meaning that original screen velocity will change

$\dfrac{0.4043m}{3.0 \times 10^{-2}m} = n/2 - 1$ = no. of bars = 5.74 ⇒ 6 bars.//

↳ no of 3.0 cm space

Note: It is possible this question may require some iteration.

$6 \times a + 3.0 \times 10^{-2}m \times 6 = 0.4043m$

a = 3.7cm approx for bar width //

②

1 (b) $Q = 150\ 000 m^3/d$

$\nu = 0.893 \times 10^{-6} m^2/s$

$d = 0.15mm$

$S = 1.03 \Rightarrow \rho = 1030\ kg/m^3$

$V_H = 0.2$ scour velocity

ideal sedimentation tank

$k = 0.04$

$f = 0.03$

Find ~~up first~~

~~$V_P = \frac{g(sg_P - 1) d_P^2}{18\nu}$~~

~~$= \frac{9.81 m/s^2 (1.03 - 1)(0.15 \times 10^{-3})^2}{18 \times 0.893 \times 10^{-6} m^2/s}$~~

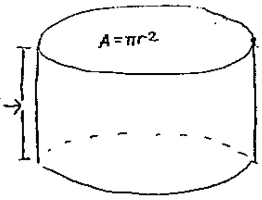
Find scour velocity $V_H = \left[\frac{8k(s-1)gd}{f}\right] = \left[\frac{8(0.04)(0.25)(9.81)(0.15 \times 10^{-3} m)}{0.03}\right]^{1/2}$

$= 0.01981 m/s$

horizontal velocity $V_{HORT} = 0.2 \times V_H = 3.962 \times 10^{-3} m/s$

Q/V_H = gives area $= \frac{150\ 000 m^3/d}{0.01981 m/s} \times \frac{1 day}{24hrs} \times \frac{1hr}{3600s}$

$= 87.64 m$ = area of circular portion



$\pi r^2 = 87.64 m$

$r = 5.3m$ radius or 10.6 diameter

peak horizontal flow velocity $V_{HORT} = \frac{Q}{Ax}$

1 (c) $Q = 500m^3/d$

TSS = 2500mg/L

SLR = $10L/m^2$-min

T = 30°C

air solubility temp = ~~30°C~~ 15.7mL/L

$f = 0.75$

$D = 9.0m$

A - S = 0.012mL/mg

Detention time, t = 2.5h.

$Q \times TSS$ = organics flow rate

$= 500 m^3/d \times 2500 mg/L \times \frac{1 \times 10^{+3} L}{1m^3}$

$= 1250g/d = 1.250 kg/d$

Note (w/o recycle)

$$\frac{A}{S} = \frac{1.3 s_a (fP - 1)}{S_a} = \frac{1.3 \times 15.7 mL/L (0.5P - 1)}{2500 mg/L} = 0.012 mL/mg$$

$$\left(\frac{\frac{A}{S} \cdot S_a}{1.3 s_a} + 1\right) \frac{1}{f} = P = \left(\frac{0.012 \cdot 2500 mg/L}{1.3 \cdot 15.7 \frac{mL}{L}} + 1\right) \frac{1}{0.75} = 1.960\ atm$$

$P = 1.960\ atm = \frac{p + 101.35}{101.35} \Rightarrow p = 97.28 kPa$

$$A = \frac{(500 m^3/d) / (10L/m^2 - min) \cdot (2.5hrs)(60mins/1hr)}{} \cdot \frac{(10^3 L/m^3)}{(1440 min/d)}$$

$= 34.72 m^2$ (req surface area w/o recycle)

(w/ recycle) a) $P = \frac{p + 101.35}{101.35} \Rightarrow$ some number $\Rightarrow$ isolate p (kPa)

b) $\frac{A}{S} = \frac{1.3 s_a (fP - 1) R}{S_a} \Rightarrow R = \left(\frac{\frac{A}{S} \cdot S_a}{1.3 s_a}\right) \frac{1}{fP - 1}$

$\frac{A}{S} \to 0.012$, $s_a \to 15.7$ mL/L, $S_a \to 2500mg/L$

$f = 0.75$

P ⇒ from a

$Q_R = R \times Q = Q_R > Q$

$A = (Q_R + Q)(10^3 L/m^3) / (SLR \times \frac{1440 min}{d}) = A_R > A$ //

Q. (a) $Q = 16\,000\ m^3/d$

$FeSO_4 \cdot 7H_2O$ coag dosage of 60mg/L

alk of 6mg/L as $CaCO_3$

(3)

(i) $M_{TSS} = 16\,000\ m^3/d \times 60\ mg/L = 960\ kg/d$

2 (b) 200mg/L $Ca(OH)_2$ (4)

Q = 1500 m^3/d

1 ton/d sludge production

Influent: PO_4^{3-} = 19mg/L as P   Effluent: PO_4^{3-} = 0.9mg/L

Ca^{2+} = 150 mg/L Ca^{2+} = 30mg/L

$10\,Ca^{2+} + 6PO_4^{3-} + 2OH^- \leftrightarrow Ca_{10}(PO_4)_6(OH)_2$ ↳ TSS

$Ca^{2+} + CO_3^{2-} \longleftrightarrow CaCO_3$

① compute for Equivalent weights

$[Ca_{10}(PO_4)_6(OH)_2] \Rightarrow \frac{1}{6} \times \frac{1004}{31} \left(\frac{1}{25.05}\right)^{-1}$ ↳ Molar Mass

mole ratio ↳ Phosphorus

10 (40) + 6(31 + 64) + (18)2 = 1004

$= \frac{1}{6} \times \frac{1004}{31} \times 25.05$

= 135.22 mg/L

$Ca^{2+} + CO_3^{2-} \leftrightarrow CaCO_3$

$[CaCO_3] = \frac{100.1}{40.1} \times 150\,mg/L = 374.44\,mg/L$

$[Ca^{2+}] = \frac{10 \text{ mols } Ca^{2+}}{6 \text{ mols } PO_4^{3-} \text{ as P}} \times \frac{40}{31}$

Given: MLSS = 2500 mg/L   T = 30 min   in 1L grad cyl.   V = 265 mL

3. (i) SVI (mL/g) = ~~mL × 1000 MLSS g/L~~ $\dfrac{(265\ mL/L) \times 1000\ mg/g}{2500\ mg/L} = 106\ mL/g$ (5)

clear, good quality effluent

(ii)

(iii)

3. (c) (i) $Q = 8000\ m^3/d \times 145\ mg/L \times \frac{1000L}{1m^3} \times \frac{1kg}{1000000mg}$ = 1160 kg/d BOD loading rate

~~Volume of aeration tank = 3.2 m3/d/m2~~

BOD$_L$ loading Rate = 0.12 kg/m3 ~~220 m3/d~~ × 8000m3/d

= ~~1760 000 kg/d~~ 960 kg/d

BOD$_L$ volumetric loading rate

$= \frac{960 \text{ kg/d}}{2500\ m^3} = 0.384\ kg/d/m^3$ //

(ii) F/M ratio MLVSS = 0.85 MLSS

= 0.85 × 2800 mg/L

= 2380 mg/L

⑥

$F/M = \frac{8000 \times 145}{2500m^3 \times 2380} = 0.195\ kg\ BOD/kg\ MLVSS \cdot d$

↳ MLVSS

(iii)

$HRT = \frac{V}{Q} = \frac{2500m^3}{8000\ m^3/d} = 0.3125\ d\ (7.5hrs)$

(iv)

SRT ⇒ $HRT = \frac{SRT}{X}\left(\frac{Y(S_0 - S)}{(1 + k_d\ SRT)}\right)$

or

$\frac{\text{Volume of aeration tanks}}{\text{Volume of waste sludge passing through}} = \frac{2500m^3}{220m^3/d} = 11.36$ days //

(v) $RAS = \frac{Q_r}{Q} = \frac{3320}{8000} = 0.415 \approx 42\%$

(vi)

$BOD = \frac{145 - 25}{145} = 82.8\%$ //

$SS = \frac{120 - 20}{120} = 83.3\%$ //

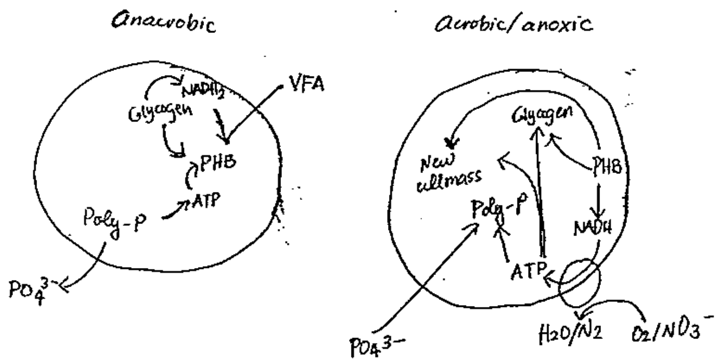
(d)

(i) Nitrification: Biological oxidation of ammonia/ammonium to nitrite followed by oxidation of nitrite to nitrate

Transformation of ammonia to nitrite ⇒ limiting step in nitrification

Denitrification: microbially facilitated process of nitrate reduction performed by heterotrophic facultative anaerobic bacteria that leads to production of molecular nitrogen (N_2)

(ii)



(4) (a) $Q = 75\,000\ m^3/d$ → use nitrogen as basis as process takes longer!

$$\mu_n = \left[\frac{\mu_{n,m} N}{K_n + N}\right]\left[\frac{DO}{K_o + DO}\right] - kd_n$$

$$= \left[\frac{0.75\,(0.500)}{0.74 + 0.5}\right]\left[\frac{2.0}{0.5 + 2.0}\right] - 0.08$$

$$= 0.162\ d^{-1}$$

$$SRT\ (\text{theoretical}) = \frac{1}{\mu_n} = 6.175\ \text{days}$$

$$SRT\ (\text{design}) = \frac{1}{\mu_n} \times 1.6 = 9.880\ \text{days}$$

(b)

$$S = \frac{k_s(1 + kd\,SRT)}{SRT(\mu_m - kd) - 1} = \frac{20\,(1 + 0.12\,(9.880))}{9.880\,(6.0 - 0.12) - 1}$$

$$= 0.7656\ g/m^3$$

$P_{x,bio}$ = ↳ excess sludge (to convert to VSS)

$$\frac{YQ(S_o - S)}{1 + kd\,SRT} + \frac{fd\,kd\,YQ(S_o - S)SRT}{1 + kd\,SRT} + \frac{Y_n Q(NO_x)}{1 + kd_n SRT}$$

A, B, C respectively (C → need to work out this value separately)

$$A = \frac{0.4\,(75\,000)(250 - 0.7656)}{1 + 0.12 \times 9.880} = 3421\ kg/d$$

$$B = \frac{0.15(0.12)(75\,000)(0.400)(240 - 0.7656)(9.880)}{1 + 0.12 \times 9.880}$$

$$= 583.99\ kg/d$$

C ⇒ $NO_x = TKN - Ne - 0.12\,P_{x,bio}/Q$ ⇒ work this out "backwards"

$$= 30.0 - 0.500 - 0.12\,\frac{P_{x,bio}}{Q}$$

① Assume $P_{x,bio} = 1064 \times 10^3$

then $NO_x = 27.798\ g/m^3$

Check with $P_{x,bio} = A + B + C = 3421 + 583.9 + \dfrac{(75\,000)(27.789)(0.12)}{1 + 0.18 \times 9.880}$

$$= 3421 + 583.9 + 139.690$$

$$= 4144.59$$ ⇒ iterate new value of $P_{x,bio}$

↳ find NOx ⇒ $P_{x,bio}'$

↳ check against $P_{x,bio}$ for iteration

↳ do this until $P_{x,bio}$ and $P_{x,bio}'$ converge, but a few iterations (two sets) should be enough to demonstrate your understanding.

i.e. $P_{x,bio} = 1000 \times 10^3$

$NO_x = 27.9$

$$P_{x,bio} = 3421 + 583.9 + \frac{Y_n Q(NO_x)}{1 + kd_n SRT}$$

4 (c) O_2 requirements

$$R_O = Q(S_o - S) - 1.42\, P_{x,bio} + 4.33\, Q\, (NO_x)$$

$$= 75000\,(250 - 0.7656) - 1.42\, P_{x,bio} + 4.33\,(75000)\,(NO_x)$$

= ______ kg/d (O_2 requirement)

↳ based on $P_{x,bio}$, NO_x

~~For every 1g of N oxidized, 3.57 g of cells of $CaCO_3$ is consumed~~

(8)