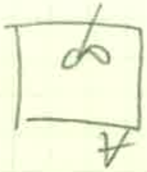
CENG 340 | PSET 10 | KEY

(2) Given: Batch Reactor



$\mu_{max} = 6.5 \ day^{-1}$

$K_s = 35 \ mg/L$

$k_d = 0.1 \ day^{-1}$

$X_0 = 0.25 \ mg/L$

(a) Find X @ $t = 3 \ days$

$$\frac{dm}{dt} = \cancel{\dot{m}_{in}} - \cancel{\dot{m}_{out}} + \dot{m}_{rxn}$$

no flow

$$\forall \frac{dX}{dt} = \forall \left(\frac{dX}{dt}\right)_{rxn} = \left(\underbrace{\frac{\mu_{max} S X}{K_s + S}}_{\text{growth}} - \underbrace{k_d X}_{\text{death}}\right)\forall$$

but $S >> K_s$

$$V \frac{dX}{dt} = (\mu_{max} X - k_d X)\forall$$

$$\frac{dX}{dt} = (\mu_{max} - k_d) X$$

$$\int_{X_0}^{X} \frac{dX}{X} = \int_0^t (\mu_{max} - k_d) dt$$

$$\ln X \Big]_{X_0}^{X} = (\mu_{max} - k_d) t \Big]_0^t$$

$$\ln \frac{X}{X_0} = (\mu_{max} - k_d) t$$

$$X = X_0 e^{(\mu_{max} - k_d)t} = 0.25 e^{(6.5 - 0.1)3}$$

$$\boxed{X = 5.5 \times 10^{7} \ \frac{mg \ cells}{L}}$$

(b) Find t for $X = 2X_o$

$$X = X_o e^{(\mu_{max} - k_d)t}$$

$$2\cancel{X_o} = \cancel{X_o} e^{(\mu_{max} - k_d)t}$$

7 pts

$$\ln 2 = (\mu_{max} - k_d)t$$

$$t = \frac{\ln 2}{\mu_{max} - k_d} = \frac{\ln 2}{6.4} = 0.108\,\text{day} \times \frac{24\,\text{h}}{\text{day}}$$

$$\boxed{t = 2.6 \text{ hours}}$$

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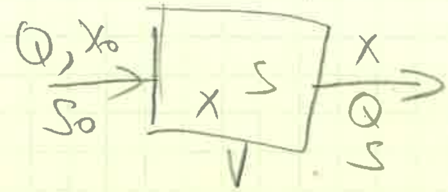
③

Given: CMFR, $X_o = 0$, Steady-State.

$$-\frac{dS}{dt} = kXS$$



Growth: $$\frac{dx}{dt} = -Y\frac{dS}{dt}$$

14 pts

Death: $$\frac{dx}{dt} = -k_d X$$

Mass Balance on X

$$\cancel{\frac{V\,dx}{dt}} = \cancel{QX_o} - QX + \left(\frac{dx}{dt}\right)_{rxn} V$$

$$0 = -QX + (YkXS - k_d X)V$$

$$\frac{Q}{V}\cancel{X} = \cancel{X}(YkS - k_d)$$

$$\boxed{S = \frac{\frac{Q}{V} + k_d}{Yk}}$$

$$\boxed{S = \frac{\frac{1}{\theta} + b}{Yk}}$$

④ Given CMFR, no recycle

$\mu_{max} = 4.2 \text{ day}^{-1}$

$K_s = 40 \text{ mg/L}$

$k_d = 0.1 \text{ day}^{-1}$

$S_o = 200 \text{ mg/L BOD}_u$

ⓐ Find $\theta_{c\,min}$.

$$\theta_{c\,min} = \left(\frac{\mu_{max} S_o}{K_s + S_o} - k_d\right)^{-1}$$

7 pt

$$\theta_{c\,min} = \left(\frac{4.2 \times 200}{40 + 200} - 0.1\right)^{-1}$$

$$\theta_{c\,min} = 0.294 \text{ day} \times \frac{24 \text{ h}}{1 \text{ day}}$$

$$\boxed{\theta_{c\,min} = 7.1 \text{ h}}$$

ⓑ Given $\theta_c = 20 \times \theta_{c\,min}$, Find S

$\theta_c = 20 \times 0.294 = 5.9 \text{ day}$

$$S = \frac{K_s (1 + k_d \theta_c)}{\theta_c (\mu_{max} - k_d) - 1} = \frac{40 \text{ mg/L} (1 + 0.1 \frac{1}{day} \times 5.9 \text{ day})}{5.9 \text{ day} (4.2 \frac{1}{day} - 0.1 \frac{1}{day}) - 1}$$

$$\boxed{S = 2.75 \text{ mg/L}}$$

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(5)

Given:

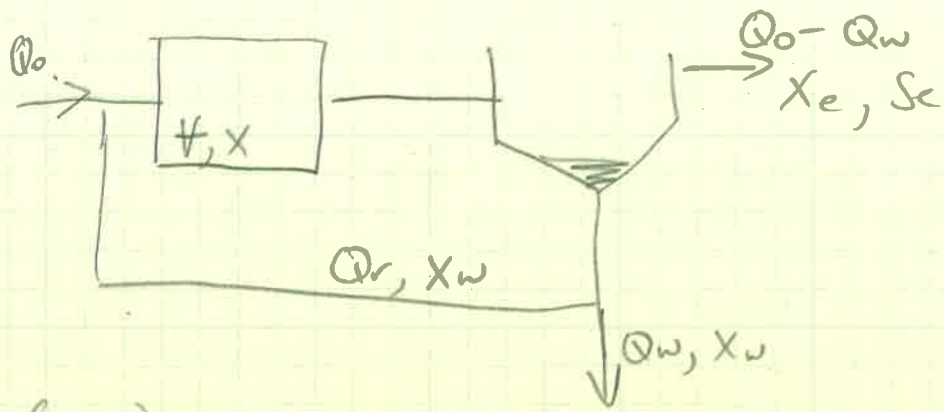
$Q_0 = 35{,}000\ m^3/day$

$SRT, \theta_c = 5\ day$

$\forall = 1640\ m^3$

$X = 2000\ mg/L$ (MLSS) $= 2000\ g/m^3$

mixed liquor suspended solids



Find mass sludge wasted per day, $Q_w X_w$

Assuming that $X_e = 0$ (no solids in the effluent):

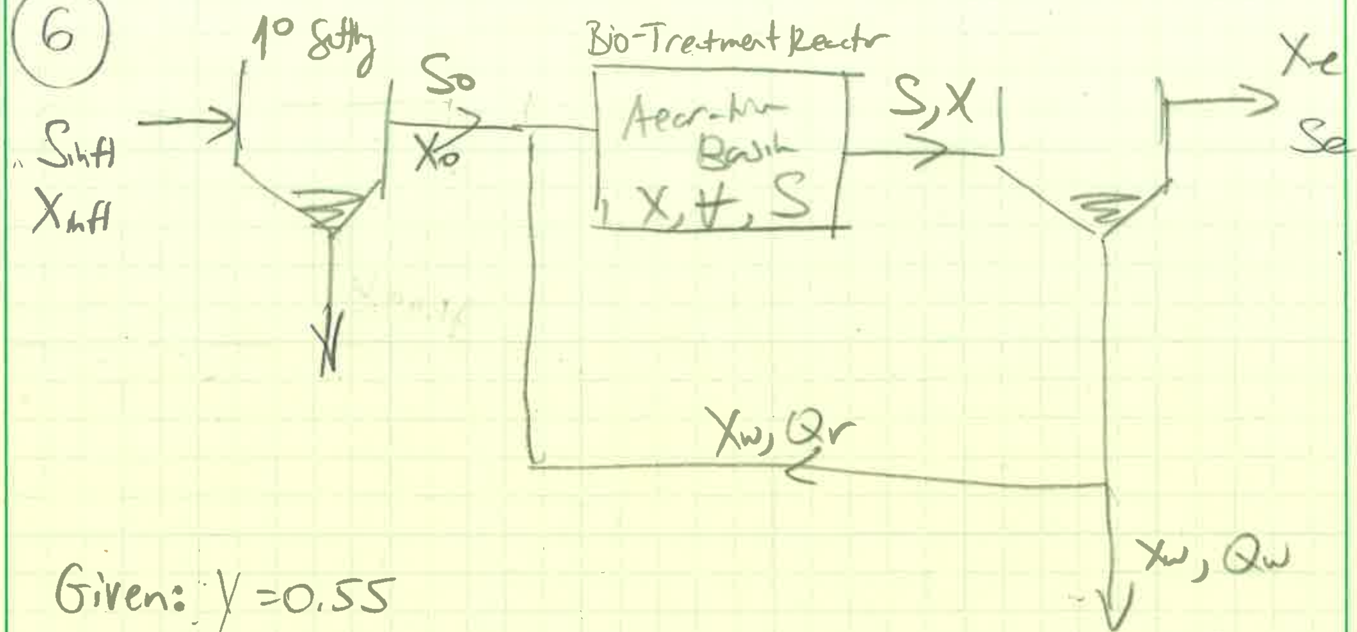
$$\theta_c = \frac{X\forall}{X_w Q_w} \Rightarrow X_w Q_w = \frac{X\forall}{\theta_c}$$

$$X_w Q_w = \frac{1640\ m^3 \times 2000\ g/m^3}{5\ days} = 656{,}000\ g/day$$

$$X_w Q_w = 656{,}000\ g/day \times \frac{1\ kg}{1000\ g} = 656\ kg/day$$

$$\boxed{X_w Q_w = 656\ kg/day}$$

⑥



Given: $Y = 0.55$

$k_d = 0.05 \text{ day}^{-1}$

$k_s = 10 \text{ mg/L}$

people, $n = 150{,}000$

$q = 225 \frac{L}{\text{day} \cdot \text{person}}$

$\dot{m} = 0.1 \text{ kg } \frac{BOD_5}{\text{day} \cdot \text{person}}$

$S_e = 20 \text{ mg/L}$

$X_e = 20 \text{ mg/L}$

$X = 4300 \text{ mg/L}$

$X_w = 15{,}000 \text{ mg/L}$

$X_{infl} = 200 \text{ mg/L}$

$X_o = 100 \text{ mg/L}$

$SRT = 4 \text{ days}$

ⓐ $\forall = ?$

First calculate Q_o:

$Q_o = 150{,}000 \text{ people} \times 225 \frac{L}{\text{day} \cdot \text{person}}$

$Q_o = 33.75 \times 10^6 \frac{L}{da}$

Calculate $S_{influent}$:

$$S_{influent} = \frac{0.1 \frac{\text{kg } BOD_5}{\text{person}}}{225 \frac{L}{\text{person}}} \times 10^6 \frac{mg}{kg}$$

$S_{influent} = 444 \text{ mg/L}$

To calculate $\forall$, use the following eq:

$$\frac{1}{\theta_c} = \frac{Q_o Y}{\forall X}(S_o - S) - k_d$$

6 a. cont.

3pt Since ~30% of BOD is removed in primary treatment,

$$S_o = 0.7 \times S_{influent} = 0.7 \times 444 \, mg/L$$

$$S_o = 310 \, mg/L$$

$$\frac{1}{\theta_c} = \frac{Q_o Y}{V X}(S_o - S) - k_d$$

$$V = \frac{\theta_c Q_o Y}{X}(S_o - S) - k_d \times \theta_c$$

$$= \frac{4 \, day \times 33.75 \times 10^6 \, L/day \; 0.55 \, g \, TSS/g \, BOD}{4300 \, mg \, TSS/L}\left[444 \, mg/L \times 0.7 - 20 \, mg/L\right]$$

$$- 0.05 \, \frac{1}{day} \times 4$$

$$\boxed{V = 4.2 \times 10^6 \, L}$$

b Aeration period = HRT = θ

3pt $$\theta = \frac{V}{Q} = \frac{4.2 \times 10^6 \, L}{33.75 \times 10^6 \, \frac{L}{day}} = 0.12 \, day = 2.9 \, h$$

$$\boxed{\theta = 2.9 \, h}$$

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(c) Calculate $Q_w X_w$

3 pt $\theta_c = \frac{\forall X}{Q_w X_w} \Rightarrow Q_w X_w = \frac{\forall X}{\theta_c} = \frac{4.2 \times 10^6 L \times 4300 \frac{mg\ TSS}{L}}{4\ day}$

$Q_w X_w = 4.52 \times 10^9 \frac{mg\ TSS}{day} \times \frac{1\ kg}{10^6\ mg}$

$$\boxed{Q_w X_w = 4{,}515 \frac{kg}{day}}$$

(d) If Q_w is increased, SRT will decrease.

1 pt

(e) Calculate food to microorganism ratio: F/M

3 pt $F/M = \frac{Q_o S_o}{X V}$

Using TSS for X

$F/M = \frac{33.75 \times 10^6\ L/day \times 444\ mg/L \times 0.7}{4300 \frac{mg\ TSS}{L} \times 4.2 \times 10^6\ L}$

$$\boxed{F/M = 0.58 \frac{kg\ BOD}{kg\ TSS \cdot day}} = 0.58 \frac{lb\ BOD}{lb\ TSS \cdot day}$$

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(b) (e) cont.

using VSS for X

$$F/M = \frac{33.75\times10^6 \frac{L}{day} \times 444 \frac{mg}{L} \times 0.7}{4300 \frac{mg\ TSS}{L} \times 0.6 \frac{VSS}{TSS} \times 4.2\times10^6\ L}$$

Both answers: 0.58 & 0.97 acceptable.

$$\boxed{F/M = 0.97 \frac{kg\ BOD}{kg\ VSS \cdot day}} = 0.97 \frac{lb\ BOD}{lb\ VSS \cdot day}$$

(f) Mean cell residence time equals solids retention time $= \theta_c$

1pt

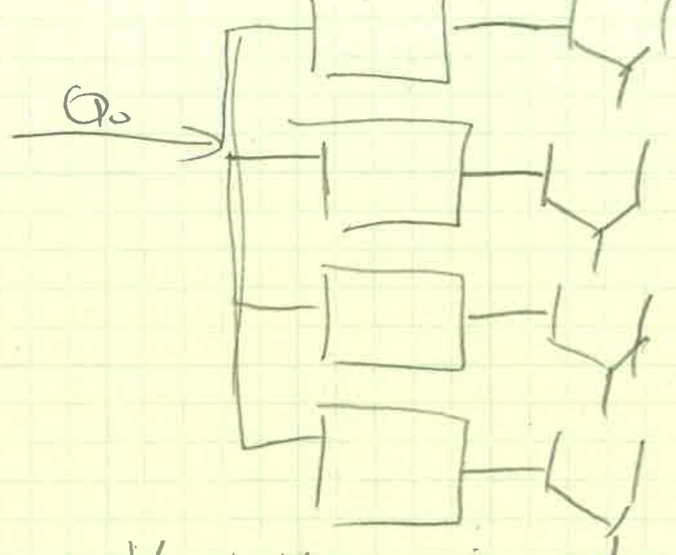
(7) Given

$\theta = 6h$

$Q = 5\times10^{6}\ \frac{gal}{day}$

$X = 3000\ \frac{mg\ TSS}{L}$

$S_o = 150\ mg/L$



(a) Calculate F/M

$$F/M = \frac{Q_o S_o}{\forall X}$$

9 pts

$\forall_{tot}$ is the combined volume of the four aeration basins.

Find $\forall_{tot}$ $\Rightarrow$ $\forall_{tot} = Q_{tot} \times \theta = 5\times10^{6}\ gal/day \times 6h \times \frac{1\ day}{24h}$

Note: I calculated total volume of the aeration basins b.c. they are operated in parallel..

$\forall_{tot} = 1.25\times10^{6}\ gal$

$$F/M = \frac{5\times10^{6}\ \frac{gal}{day} \times 150\ mg/L}{1.25\times10^{6}\ gal \times 3000\ \frac{mg\ TSS}{L} \times 0.6\ \frac{mg\ VSS}{mg\ TSS}}$$

$$\boxed{F/M = 0.33\ \frac{lbs\ BOD}{lbs\ VSS \cdot day}}$$

(b) The operator should reduce the amount of solids wasted (or increase the amount of solids that are recycled) to increase solids in the aeration basin.

5 pts