CENG 340 | PSET 8 | KEY

(1) Given: $BOD_u = 4\ mg/L = L_0$

$k = 0.3\ day^{-1}$

$t = 5\ days$

$y(5) = L_0(1 - e^{-kt})$

$y(5) = 4\ mg/L\,(1 - e^{-0.3\times5}) = 3.1\ mg/L$

12pt

6pt $\boxed{\text{Oxygen used} = 3.1\ mg/L}$

BOD remaining, $L(5) = L_0 - y(5) = 4 - 3.1 = 0.9\ mg/L$

6pt $\boxed{\text{BOD remaining} = 0.9\ mg/L}$

(2)

$BOD_5 = 10\ mg/L$ (full strength) $DO_{in} = 8\ mg/L$

$NH_3-N = 2\ mg/L$ (full strength)

Diluted by 10

$BOD_5 = \frac{10}{10} = 1\ mg/L$ (diluted, in bottle)

$NH_3-N = \frac{2}{10} = 0.2\ mg/L$ (diluted, in bottle)

(a) Calculate NBOD (= nitrogenous ThOD)

$\underset{14g, as\ N}{NH_3} + \underset{64\ g}{2O_2} \rightarrow NO_3^- + H_2O + H^+$

$NBOD = 0.2\ mg/L\ NH_3-N \times \frac{64\ g\ O_2}{14\ g\ NH_3-N} = 0.9\ mg/L$ (4 pt)

Tot

(b) Calculate BOD_u or L_o in bottle

(option 1) $BOD_5 = 1 mg/L = y(5)$

$$y = L_o(1 - e^{-kt}), \text{ Assume } k = 0.25 \text{ day}^{-1}$$

$$L_o = \frac{y}{1-e^{-kt}} = \frac{1 mg/L}{1-e^{-0.25 \times 5}} = 1.4 \ mg/L$$ (4 pt)

After a very long time, L_o (BOD_u) & NBOD will be consumed, so:

O_2 consumed $= L_o + NBOD = 1.4 + 0.9 = 2.3 mg/L$

$DO_{final} = DO_{in} - O_2 consumed =$

$= 8 mg/L - 2.3 mg/L = 5.7 mg/L$

12 pt $\boxed{DO_{final} = 5.7 mg/L}$

for $k = 0.2 - 0.3$ day^{-1}

$DO_{final} = 5.5 - 5.8$

(option 2) Calculate NBOD, same as in option 1:

$NBOD = 0.9 mg/L$

To calculate (estimate) BOD_u (L_o), assume

$BOD_5 = \frac{2}{3} BOD_u$

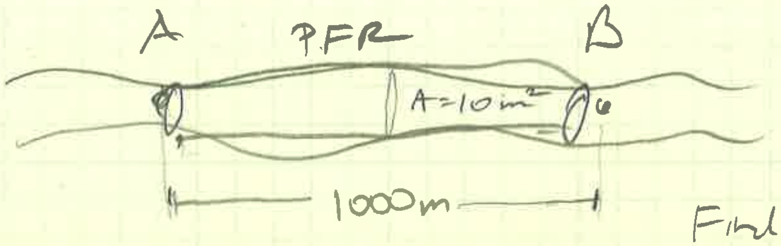
$BOD_u = 1.5 \ BOD_5 = 1.5 \times 1 = 1.5 mg/L$

DO consumed $= 1.5 + 0.9 = 2.4 mg/L$

$DO_{final} = DO_{in} - DO_{cons} = 8 - 2.4 = 5.6$

$\boxed{DO_{final} = 5.6 mg/L}$

(3)



For each sample:

$Y_5 = L_0(1 - e^{-k_{lab} 5})$

Find k_r

In the Lab

At point A

$BOD_5 = 7.2 \text{ mg/L}$

$L_{0_A} = \dfrac{Y_5}{1 - e^{-k_{lab} 5}}$

$L_A = \dfrac{7.2}{1 - e^{-k_{lab} 5}}$

At point B

$BOD_5 = 3.5 \text{ mg/L}$

$L_{0_B} = \dfrac{Y_5}{1 - e^{-k_{lab} \times 5}}$

$L_B = \dfrac{3.9}{1 - e^{-kt}}$

$$\frac{L_B}{L_A} = \frac{\dfrac{3.9}{\cancel{1 - e^{-kt}}}}{\dfrac{7.2}{\cancel{1 - e^{-kt}}}} = \frac{3.5}{7.2}$$

In the river:

$$PFR \Longrightarrow L_B = L_A e^{-k_r t}, \quad t = \theta = \frac{V}{Q} = \frac{10{,}000 \text{ m}^3}{100 \text{ m}^3/\text{h}} = 100 \text{ h}$$

$$e^{-k_r t} = \frac{L_B}{L_A}$$

$$-k_r t = \ln\left(\frac{L_B}{L_A}\right)$$

14 pt

$$k_r = \frac{-\ln\left(\frac{L_B}{L_A}\right)}{t} = \frac{-\ln\left(\frac{3.9}{7.2}\right)}{100 \text{ h} \times \frac{1 \text{ day}}{24 \text{ h}}}$$

$$\boxed{K_r = 0.15 \text{ day}^{-1}}$$

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@ 20°C

$y_5 = 4.15\ mg/L$

$$L_o = \frac{y_5^{20}}{1-e^{-k_{20}\times 5}}$$

@ 35°C

$y_5 = 6.56\ mg/L$

$$L_o = \frac{y_5^{35}}{1-e^{-k_{35}\times 5}}$$

* L_o not dependent on temperature

$$k_T = k_{20}\,\theta^{T-20}$$

$$k_{35} = k_{20}\,\theta^{35-20}$$

$$k_{35} = k_{20} \times 1.05^{15}$$

$$k_{35} = 2.08\,k_{20}$$

$$L_o = \frac{4.15}{1-e^{-5k}}$$

$$L_o = \frac{6.56}{1-e^{-5\times 2.08k}}$$

$$\frac{4.15}{1-e^{-5k}} = \frac{6.56}{1-e^{-5\times 2.08k}}$$

10 pt if get this far!

Solve for k using solver

$k = 0.12\ \frac{1}{day}$

$L_o = 9.2\ mg/L$

12 pt

$$\boxed{BOD_u = 9.2\ mg/L}$$

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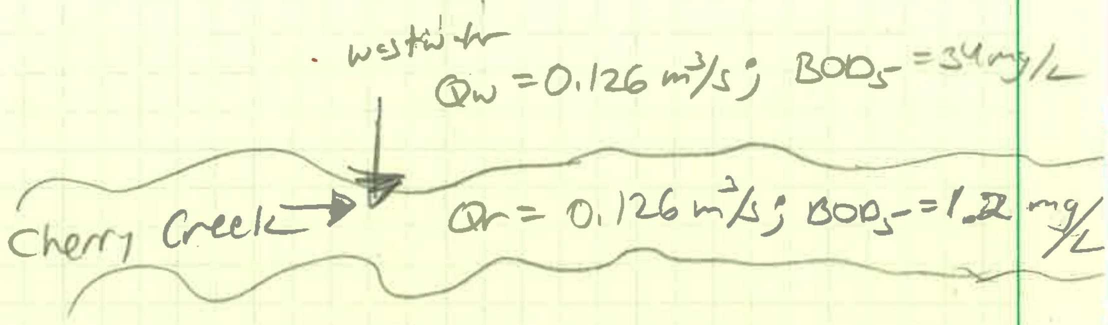

Calculate L_o after mixing $\equiv L_m$

First Calculate L_o for the river $\equiv L_r$ $\quad k_r = 0.09\ d^{-1}$

$$L_r = \frac{y_5}{1-e^{-5k_r}} = \frac{1.2}{1-e^{-5\times0.09}} = 3.31\ mg/L$$ 4pt

Similarly, calculate L_o for the wastewater $\equiv L_w$ $\quad k_w = 0.222$

$$L_w = \frac{y_5}{1-e^{-5k_w}} = \frac{34}{1-e^{-5\times0.222}} = 50.7\ mg/L$$ 4pt

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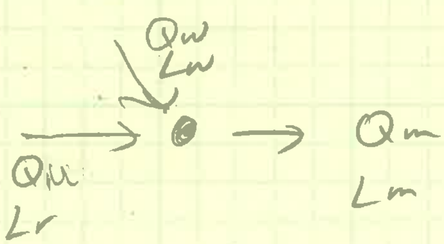
Conduct Mass Balance at point of mixing



$Q_{mix} = Q_w + Q_u$

$Q_{mix} = 0.252\ m^3/s$

$$Q_m = Q_w + Q_r$$

12pt

4pt

$$Q_m * L_m = Q_r L_r + Q_w L_w$$

$$L_m = \frac{Q_r L_r + Q_w L_w}{Q_w} = \frac{0.126 * 3.31 + 0.126 * 50.71}{2 * 0.126}$$

$$\boxed{L_m = 27\ mg/L}$$

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① Wastewater Meat: $k_{20} = 0.2\ dy^{-1}$

$BOD_5 = 2100\ g/m^3$

$\theta = 1.05$

$y(5) = L_o(1 - e^{-kt})$

$$L_o = \frac{2100}{1 - e^{-0.2\times5}} = 3322\ g/m^3$$

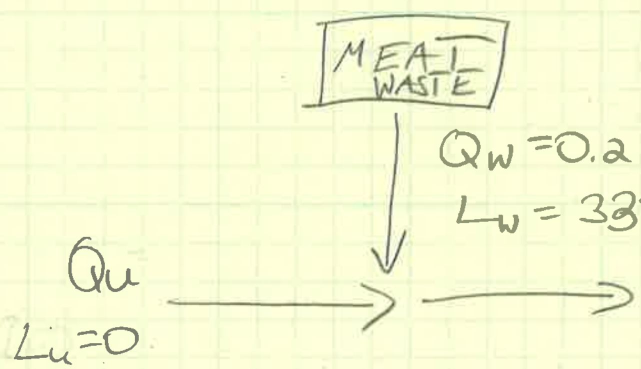
② Calculate k values for summer & winter:

Summer → $k = k_{20}\theta^{26-20} = 0.2\times1.05^{6} = \underline{0.268\ dy^{-1}}$

Winter → $k = k_{20}\theta^{6-20} = 0.2\times1.05^{-14} = \underline{0.101\ dy^{-1}}$

③ Mass Balance

$\varepsilon \equiv$ % BOD removal



$Q_W = 0.2\ m^3/s$

$L_W = 3322(1-\varepsilon)$

$Q_M = Q_u + Q_W$

$BOD_5^{m} = 5\ g/m^3$

$$L_M = \frac{5\ g/m^3}{1 - e^{-k\times5}}$$

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

$0 = Q_W L_W - Q_m L_m$

④ Summer – $Q_M = Q_u + Q_W = 175 + 0.2 = 175.2\ m^3/s$

$$L_M = \frac{0.5}{1 - e^{-0.268\times5}} = 0.68\ mg/L$$

$0 = Q_W L_W - Q_M L_M$

$$L_W = \frac{Q_M L_M}{Q_W} = \frac{175.2\times0.68}{0.2} = 593\ g/m^3$$

$$L_W = 593 = 3322(1-\varepsilon)$$

$$\varepsilon = \frac{3322-593}{3322} \times 100\% = \underline{82\%}$$

(5) <u>Winter</u>

$$Q_M = Q_u + Q_W = 95 + 0.2 = 95.2 \ m^3/s$$

$$L_M = \frac{0.5}{1-e^{-0.1\times5}} = 1.3 \ g/m^3$$

14.t

$$L_W = \frac{Q_M L_M}{Q_W} = \frac{95.2 \times 1.3}{0.2} = 605 \ g/m^3$$

$$L_W = 605 = 3322(1-\varepsilon)$$

$$\varepsilon = \frac{3322-605}{3322} \times 100\% = 82\%$$

$$\boxed{\text{Percent Removal} = 82\%}$$

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DAF only: Every day − $33 m^3$, Solids Conc: 3.8%

w/ Belt Filter Press: V_{new}, solids: 24%

Mass of solids stays the same:

$$C_1 V_1 = C_2 V_2$$

12 pt

$$3.8\% \times 33 m^3 = 24\% \times V_{new}$$

$$V_{new} = 5.22\ m^3 \text{ per day}$$

$$V_{old} = 33 m^3/day \times 365 \frac{days}{y} = 12{,}045\ m^3/y$$

$$V_{new} = 5.2\ m^3/day \times 365 \frac{days}{y} = 1907\ m^3/y$$

$$\boxed{V_{sludge} \text{ savings per year} = 10{,}138\ m^3}$$

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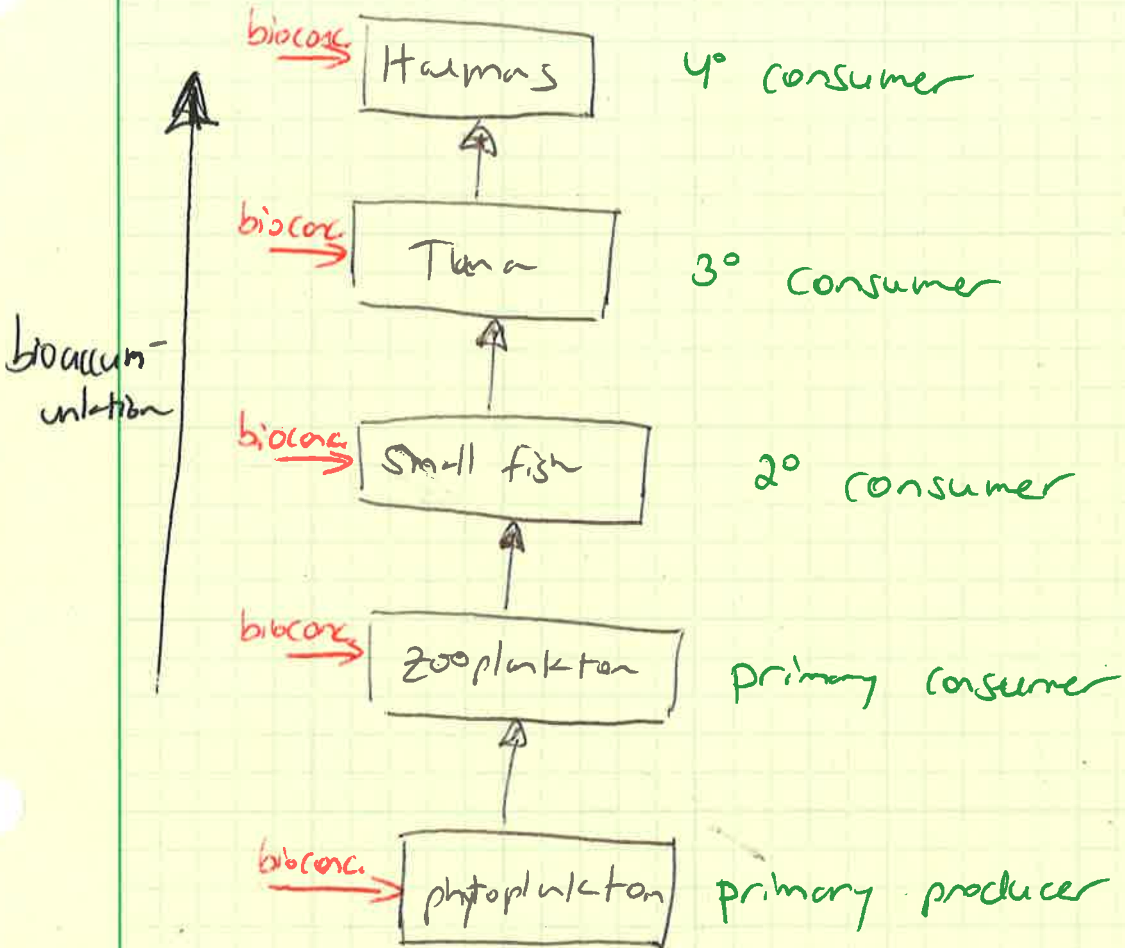

Bioconcentration is common to all species. Bioaccumulation increases as you move up the food chain.