Problem Set 7 | CENG 340 | KEY - Deborah Sills

(1) Pathogen - microorganism that causes harm to humans
SDWA - Safe Drinking Water Act
MCL - maximum contaminant level
8 pts MCLG - maximum contaminant level goal
VOC - volatile organic carbon
SOC - synthetic organic carbon
DOM - dissolved organic matter
DBP - disinfection by product
THM - trihalo methane

(2) Percent of particles retained in the clarifier equals percent of particles removed [from the water].

(a) $OFR = 0.25\ cm/s$

7 pt $v_c = OFR = 0.25\ cm/s$

$v_s = 0.3\ cm/s$

Since $v_s > v_c$, 100% of particles are retained in the clarifier, or 100% of particles are removed.

$\boxed{\text{100\% Particles retained in clarifier}}$

(b) $Q = 2 \times Q_a$

Since $OFR = \frac{Q}{A}$, $OFR = 2 \times OFR_a = 2 \times 0.25$

7 pt $OFR = 0.5\ cm/s$

Since $v_s < v_c$,

Percent removal $= \frac{v_s}{v_c} \times 100 = \frac{0.3}{0.5} \times 100 = 60\%$

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(2) b. cont.

$\boxed{\text{60\% of particles removed from the water or 60\% of particles retained in the clarifier}}$

(3)

$$Q = 75.7 \times 10^3 \ \frac{m^3}{d}$$

$$HLR = 300 \ \frac{m^3}{d \cdot m^2}$$

$$length = 7.5 \ m$$

$$\frac{length}{width} = 1.2 \Rightarrow width = \frac{7.5}{1.2} = 6.25 \ m$$

$$A_{filter} = l \times w = 7.5 \times 6.25 = 46.9 \ m^2$$

$$HLR = \frac{Q}{A} \Rightarrow A_{tot} = \frac{Q}{HLR} = \frac{75.7 \times 10^3 \ \frac{m^3}{day}}{300 \ \frac{m^3}{d \cdot m^2}}$$

$$A_{tot} = 252 \ m^2$$

$$\text{Number of Filters} = \frac{A_{tot}}{A_{filter}} = \frac{252}{46.9} = 5.3 \text{ filters}$$

round up, and $\boxed{\text{Num. of Filters} = 6}$

(4)

4/pt (a) When pH increases from 6 to 7, the required CT increases from 87 $\frac{mg\ min}{L}$ to 124 $\frac{mg\ min}{L}$.

(b)

4/pt

(1) Increase chlorine concentration

(2) Add acid (e.g., HCl) to reduce pH to 6

(3) Use different (stronger) disinfectant, such as ozone.

(4) Increase retention time ($\theta$), by increasing volume of the reactor. (not a practical solution, but still an acceptable answer.

(5)

$$Cl_{2(gas)} \xrightarrow{H_2O} [HOCl] + [HCl] \quad (1)$$

Free chlorine $= [HOCl] + [OCl^-]$

(see Table 10.21 in the textbook)

EQUILIBRIUM RELATIONSHIP FOR HOCl & $OCl^-$:

$$[HOCl] \overset{K_a}{\rightleftharpoons} [OCl^-] + [H^+] \quad (2)$$

$pK_a = 7.5$

$K_a = 10^{-7.5}$

$$K_a = \frac{[OCl^-][H^+]}{[HOCl]}$$

$HOCl = 10\ mg/L$ at equilibrium $= 10 \frac{mg}{L} \times \frac{1\ mole}{52.5\,g} \times \frac{1\,g}{1000\,mg} = 1.9 \times 10^{-4} \frac{mole}{L}$

5 a $pH = 7.5$

$$K_a = \frac{[OCl^-][H^+]}{[HOCl]}$$

$$\cancel{10^{-7.5}} = \frac{[OCl^-][\cancel{10^{-7.5}}]}{1.9\times10^{-4}}$$

$$[OCl^-] = 1.9\times10^{-4}\ \frac{mole}{L}$$

Free Chlorine $= [HOCl] + [OCl^-] =$
$= 1.9\times10^{-4} + 1.9\times10^{-4} = 3.6\times10^{-4}\ \frac{mole}{L}$

But Free Chlorine = HOCl in Eq. 1

$$Cl_{2(g)} \xrightarrow{H_2O} \underset{\text{Free Chlorine}}{HOCl} + HCl$$

7 pt $3.6\times10^{-4}\ \frac{mole}{L}$ Free Chl. $\times \frac{1\ mole\ Cl_{2(g)}}{1\ mole\ Free\ Chl.} \times \frac{71\ g\ Cl_2}{1\ mole\ Cl_2} \times \frac{1000\ mg}{1\ g}$

$= 27$ mg/L of $Cl_2(g)$

$$\boxed{\text{Dose of } Cl_{2(g)} = 27\ mg/L \ @\ pH = 7.5}$$

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5 b. Same procedure as Part a, but

$pH = 6.5$, $[HOCl] = 1.9 \times 10^{-4} \frac{mole}{L}$

7 pH

$$K_a = \frac{[OCl^-][H^+]}{[HOCl]}$$

$$10^{-7.5} = \frac{[OCl^-][10^{-6.5}]}{(HOCl)}$$

$$[OCl^-] = 10^{-1} \times [HOCl] = 1.9 \times 10^{-5} \frac{mole}{L}$$

$$\text{Free Chlorine} = [HOCl] + [OCl^-] =$$

$$= 1.9 \times 10^{-4} + 1.9 \times 10^{-5} = 2.1 \times 10^{-4}$$

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$$Cl_{2(g)} = 2.1 \times 10^{-4} \frac{\text{mole Free Chlorine}}{L} \times \frac{1 \text{ mole } Cl_2}{1 \text{ mole Free Chl.}} \times \frac{71 g\, Cl_2}{1 \text{ mole } Cl_2} \times \frac{1000 mg}{1 g}$$

$= 14\ mg/L$ of $Cl_2(g)$

$$\boxed{\text{Dose of } Cl_{2(g)} = 14\ mg/L}$$

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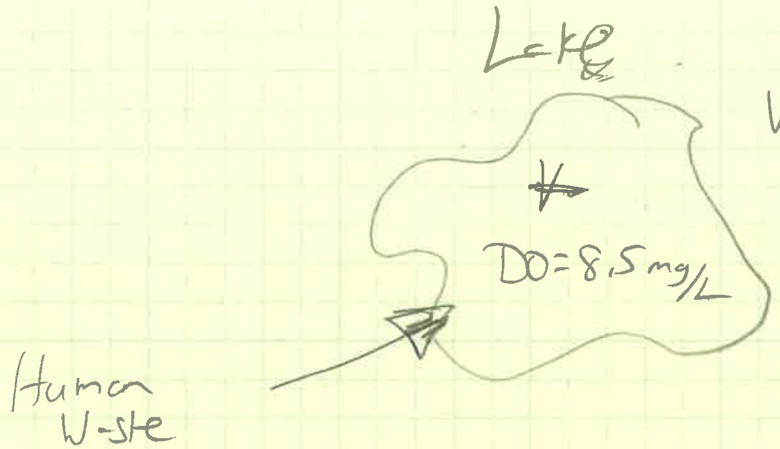


$V = 2.4 \times 10^{11}$ gal

0.2 lb of $O_2$ consuming material per day per person.
6000 people.

Total $BOD_u$ loading to the lake:

$$\frac{0.2 \text{ lb}}{\text{day} \cdot \text{person}} \times 6000 \text{ people} \times \frac{1 \text{ kg}}{2.2 \text{ lb}} = \underline{545.5 \frac{\text{kg}}{\text{day}}}$$

This number represents the amount of oxygen that will be consumed in the lake.

14 pt

Oxygen "capacity" of the lake $= V_{lake} \times 8.5$ mg/L

$$V_{lake} = 2.4 \times 10^{11} \text{ gal} \times 3.785 \text{ L/gal} \times \frac{1 \text{ m}^3}{1000 \text{ L}} = 9.1 \times 10^{8} \text{ m}^3$$

$$\text{Oxygen capacity} = 9.1 \times 10^{8} \text{ m}^3 \times 8.5 \text{ mg/L} \times \frac{1000 \text{ L}}{1 \text{ m}^3} \times \frac{1 \text{ kg}}{10^6 \text{ mg}}$$

$$\text{Oxygen capacity} = 7.7 \times 10^{6} \text{ kg}$$

$$\text{Time to depletion} = \frac{\text{Oxygen capacity}}{BOD_u \text{ Loading}} = \frac{7.7 \times 10^6 \text{ kg}}{545.5 \frac{\text{kg}}{\text{day}}} = 14{,}156 \text{ day}$$

$$\text{Time to depletion} = 14{,}156 \text{ days} \times \frac{1 \text{ year}}{365 \text{ days}} = \boxed{39 \text{ years}}$$

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7 Given 100 mg/L of ethylene glycol ($C_2H_6O_2$) &
50 mg/L of $NH_3$-N. Determine Carbonaceous
ThOD & nitrogenous ThOD

(a) Carbonaceous ThOD

$$\underset{62g}{C_2H_6O_2} + \underset{80g}{2.5O_2} \rightarrow 2CO_2 + 3H_2O$$

7pt

$$100\ \text{mg/L}\ C_2H_6O_2 \times \frac{80g\ O_2}{62g\ C_2H_6O_2} = 129\ \text{mg/L}$$

$\boxed{\text{Carbonaceous ThOD} = 129\ \text{mg/L}}$

(b) Nitrogenous ThOD

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

7pt

$$50\ \text{mg/L}\ NH_3\text{-N} \times \frac{64g\ O_2}{14g\ NH_3\text{-N}} = 229\ \text{mg/L}$$

$\boxed{\text{Nitrogenous ThOD} = 229\ \text{mg/L}}$

8\) Given: Sewage with CBOD = 100 mg/L

Assume sewage is 100% biodegradable

Find NBOD = ?

A) Since sewage is 100% biodegradable CBOD = C ThOD
(carbonaceous)

Use the following equation to calculate mg/L $NH_3-N$ per 100 mg/L CBOD

7pt

$$\overset{201\,g}{C_{10}H_{19}O_3N} + \underbrace{\overset{400\,g}{12.5\,O_2}}_{\text{ThOD Carbon} \,=\, \text{CBOD}} \longrightarrow 10CO_2 + 8H_2O + \overset{14\,g\text{ as }N}{NH_3}$$

$$100\,\frac{mg}{L}\,O_2 \times \frac{14\,g\ NH_3-N}{400\,g\ O_2} = 3.5\,\frac{mg}{L}\ NH_3-N$$

B) Since NBOD ≅ N.Prog. ThOD (always)

use the following equation to calculate NBOD

7p

$$\overset{14\,g\text{ as }N}{NH_3} + \overset{64\,g}{2O_2} \longrightarrow NO_3^- + H^+ + H_2O$$

$$\underbrace{3.5\,\frac{mg}{L}}_{\text{from part A}}\ NH_3-N \times \frac{64\,g\ O_2}{14\,g\ NH_3-N} = 16\,\frac{mg}{L}$$

$$\boxed{NBOD = 16\,\frac{mg}{L}}$$

14pt if done in one step