CEE 370	Spring 1997

Exam #1

March 11, 1997

Please answer all 5 questions. Show all work. Be neat, and box-in your answer.

1. An alum floc particle has a density of 1.04 g/mL and a diameter of 0.01 mm. (25 points)

a. Assuming it is subject only to discrete settling, what is its settling velocity at 5^{o}C in cm/s?

b. Is this particle likely to settle out in a tank that is 10 m deep and has a mean hydraulic residence time of 6 hours? Why?

c. At what rate will this particle settle in 30^{o}C water (in cm/s)?

Solution to a:

$$v_p = \frac{(\rho_p \quad \rho_w) d^2 g}{18 \mu}$$

$$v_p = \frac{(1040 - 1000)\frac{kg}{m^3}\left(1x10^{-5} m\right)^2 \left(9.8\frac{m}{s^2}\right)}{18\left(1.518x10^{-3}\frac{kg}{m \bullet s}\right)}$$

$$v_p = 0.00000143 m/s = 0.000143 cm/s$$

Solution to b:

NO!

In such a tank a particle must have a settling velocity on the order of 10 meters in a 6 hour period. This corresponds to 1.6 m/hr or 0.04 cm/s. Our particle from part a settles at only 0.00143 cm/s, so it will have no real chance to settle out while inside the tank.

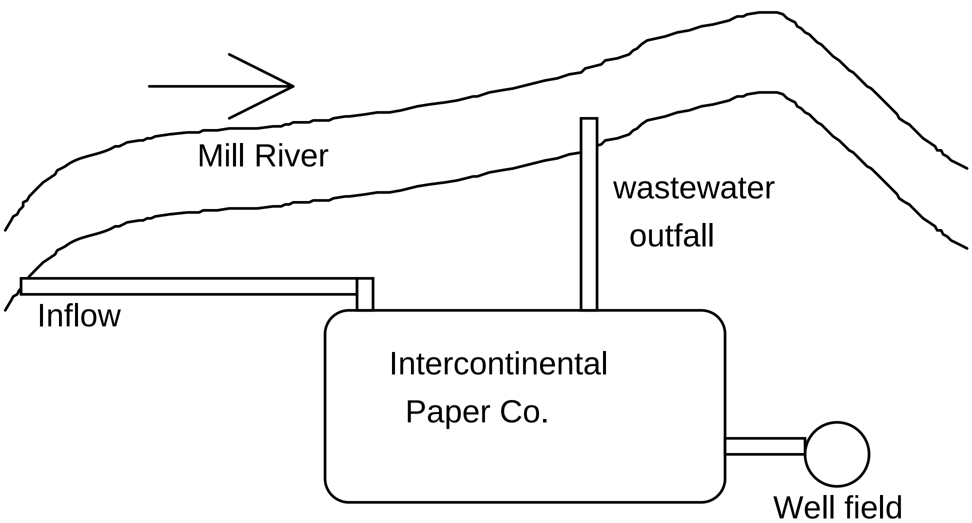
Solution to c:

$$v_p = \frac{(1040 - 995.7)\frac{kg}{m^3}(1x10^{-5}m)^2\left(9.8\frac{m}{s^2}\right)}{18\left(0.798x10^{-3}\frac{kg}{m \bullet s}\right)}$$

$$v_p = 0.00000302m/s = 0.000302cm/s$$

2. Intercontinental Paper and the Mill River (20 points)

The Intercontinental Paper Co. is discharging its wastewater directly into the Mill River. The discharge flow is 3.8 ft^3/s (cfs). They obtain half of this water from an intake 0.5 miles upstream of the wastewater outfall, and half from groundwater via a nearby well field. On average, the Mill River water upstream of IPC has a total suspended solids concentration (TSS) of 5.5 mg/L. If the Mill River has a flow of 12 cfs upstream of the IPC intake, and if the state permits a maximum TSS concentration of 15 mg/L in the Mill River, what will the allowable effluent concentration of suspended solids be for IPC?



Solution

First the downstream flow is:

$$\begin{aligned} Q_d &= Q_u + Q_e \\ &= [12 - (0.5)3.8] + 3.8 \\ &= 13.9cfs \end{aligned}$$

The solve for the effluent concentration using a mass balance:

$$
\begin{aligned}
C_e &= \frac{Q_d C_d - Q_u C_u}{Q_e} \\
&= \frac{13.9 cfs(15mg/L) - 10.1(5.5mg/L)}{3.8cfs} \\
&= 40.25\frac{mg}{L} \\
&\cong 40\frac{mg}{L}
\end{aligned}
$$

3. Calculate the ThOD of the following wastewaters: (20 points)

a. 10^{-3} moles/L of hexane, C_6H_8

b. $3x10^{-3}$ moles/L of oxalic acid, $C_2H_2O_4$

c. 30 mg/L of ethanol, CH_3CH_2OH

Solution to a.

The balanced stoichiometric equation is:

$$C_6H_8 + 8O_2 \rightarrow 6CO_2 + 4H_2O$$

The ThOD is then:

$$ThOD = 8\frac{moles - oxygen}{mole - hexane}x10^{-3}\frac{moles - hexane}{L} \times \left(\frac{32{,}000 mg - O_2}{mole - O_2}\right)$$

$$\boxed{ThOD = 256\frac{mg - O_2}{L}}$$

Solution to b.

The balanced stoichiometric equation is:

$$C_2H_2O_4 + \frac{1}{2}O_2 \rightarrow 2CO_2 + H_2O$$

The ThOD is then:

$$ThOD = 0.5\frac{moles - oxygen}{mole - oxalic\ \text{acid}}x3x10^{-3}\frac{moles - oxalic\ \text{acid}}{L} \times \left(\frac{32{,}000 mg - O_2}{mole - O_2}\right)$$

$$\boxed{ThOD = 48\frac{mg - O_2}{L}}$$

Solution to c.

The balanced stoichiometric equation is:

$$\underbrace{CH_3CH_2OH}_{46} + \underbrace{3O_2}_{96} \rightarrow 2CO_2 + 3H_2O$$

The ThOD is then:

$$ThOD = 30\frac{mg-CH_3CH_2OH}{L} \times \left(\frac{96mg-O_2}{46mg-CH_3CH_2OH}\right)$$

$$\boxed{ThOD = 62.6\frac{mg-O_2}{L}}$$

4. Calculate the concentration of the following wastewaters as mg-Carbon/L: (20 points)

a. 10^{-3} moles/L of hexane, C_6H_8

b. $3x10^{-3}$ moles/L of oxalic acid, $C_2H_2O_4$

c. 30 mg-ethanol/L, CH_3CH_2OH

Solution to a:

$$Conc. = 6\frac{moles-carbon}{mole-hexane}x10^{-3}\frac{moles-hexane}{L} \times \left(\frac{12{,}000mg-O_2}{mole-O_2}\right)$$

$$\boxed{Conc. = 72\frac{mg-C}{L}}$$

Solution to b:

$$Conc. = 2\frac{moles-carbon}{mole-oxalic\text{ acid}}x3x10^{-3}\frac{moles-oxalic\text{ aci}}{L} \times \left(\frac{12{,}000mg-O_2}{mole-O_2}\right)$$

$$\boxed{Conc. = 72\frac{mg-C}{L}}$$

Solution to C:

$$Conc. = 30\frac{mg-CH_3CH_2OH}{L} \times \left(\frac{24mg-C}{46mg-CH_3CH_2OH}\right)$$

$$Conc. = 15.7 \frac{mg - C}{L}$$

5. Short Answer (15 points)

a. Name and describe the three types of reactors discussed in class. Explain how they differ (10 points)

b. What is an autotrophic organism? (3 points)

c. What distinguishes a carboxylic acid from other chemical substances? (2 points)

Answer to a:

Batch Reactors: no flow
PFR: Plug Flow reactor; continuous flow, no mixing
CSTR: Completely Stirred Tank Reactor: continuous flow; perfect (complete) mixing

Answer to b:

Organisms that utilize inorganic carbon (i.e., carbon dioxide, carbonates) for synthesis. Algae and most other photosynthetic organisms are also autotrophs.

Answer to c:

Carboxylic acids have a -COOH group.

Appendix

Some physical constants of Water:

Temp., ^oC	Density, kg/m^3	Viscosity x 10^3, $N\text{-}s/m^2$	Kinematic Viscosity x 10^6, m^2/s
0	999.8	1.781	1.785
5	1000.0	1.518	1.519
10	999.7	1.307	1.306
15	999.1	1.139	1.139
20	998.2	1.002	1.003
25	997.0	0.890	0.893
30	995.7	0.798	0.800
35	994.0	0.725	0.729
40	992.2	0.653	0.658

Selected Chemical Constants

Element	**Symbol**	**Atomic #**	**Atomic Wt.**	**Valence**	**Electronegativity**
Aluminum	Al	13	26.98	3	1.47
Boron	B	5	10.81	3	2.01
Calcium	Ca	20	40.08	2	1.04
Carbon	C	6	12.01	2,4	2.50
Cerium	Ce	58	140.12	3,4	1.06
Helium	He	2	4.00	0	
Holmiuum	Ho	67	164.93	3	1.10
Hydrogen	H	1	1.01	1	2.20
Magnesium	Mg	12	24.31	2	1.23
Manganese	Mn	25	54.94	2,3,4,6,7	1.60
Osmium	Os	76	190.2	2,3,4,8	1.52
Oxygen	O	8	16.00	2	3.50
Potassium	K	19	39.10	1	0.91
Sodium	Na	11	22.99	1	1.01
Sulfur	S	16	32.06	2,4,6	2.44