UNIVERSITY OF WATERLOO
Department of Civil Engineering
Water Quality Engineering
Civ. E. 375

QUIZ #2

Winter 2006
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****** 50 Minutes ******

NAME: solution set

ID: ____________________

Answer all questions in the space provided.
(Use the backs of the pages if you require more space.)

MARKING SCHEME:

PART A		PART B	
1.	/2	6.	/4
2.	/4	7.	/6
3.	/2	8.	/6
4.	/2		
5.	/2		

/28

BONUS QUESTION /3

TOTAL: ____________ /28

PART A - *Short* Answer (point form acceptable)

1. The Provincial Water Quality Objectives are the starting point for the derivation of effluent requirements. What are the two cases that determine whether degradation is permitted?

p. 5-5.

(2)

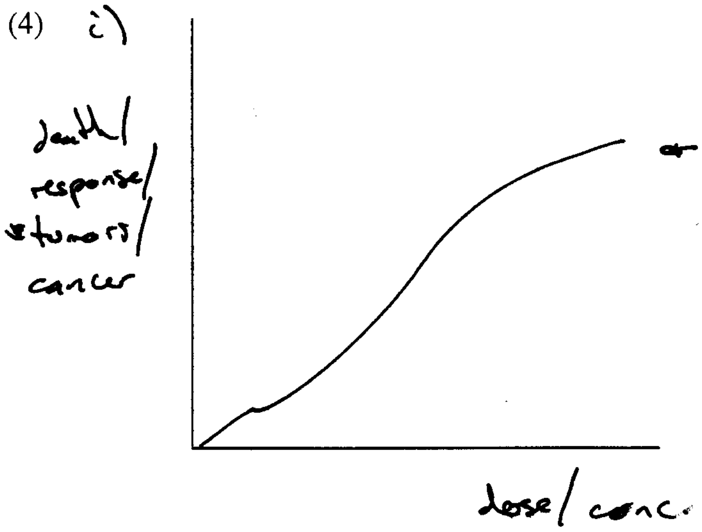
[1] • case A - water quality is better than objectives
- some degradation is allowed (3.2.1. policy 1)

[1] • case B - water quality does not meet objectives
- no further degradation is permitted (3.2.2. policy 2)

2. Define "Cancer Potency Factor". Illustrate CPF by sketching the appropriate curve and labeling the graph below. What are the parameters that are assumed in the determination of drinking water exposure risks to humans?

(4) i)

[2]



← or → - risk of cancer to 1 million people or organisms

ii) - 2L water/day consumption
- 70kg adult.

[2]

3. Arolclor 1248 ($C_{12}H_6Cl_4$) has the physical/chemical characteristics shown at right. Giving your reasons, in what environmental compartment(s) would you expect Aroclor to become <u>most</u> concentrated following its use? (Do not calculate equilibrium concentrations.)

gmw = 292 g/mol
Vapour Pressure = 1.5 x 10^{-4} mm Hg
log K_{ow} = 5.95
water solubility = 0.054 mg/L

(2)

[2] high Kow, therefore in solids or organics

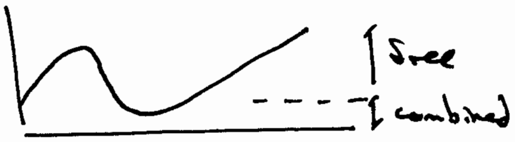
4. Define "free residual chlorine" and "combined residual chlorine".

(2) p. 3-57, 3-59

[1] free residual chlorine: HOCl + OCl$^-$

[1] combined residual chlorine: NH_2Cl, $NHCl_2$, NCl_3 (chloramines)

or [1]



5. If a solution has an equilibrium OH$^-$ concentration of [OH$^-$] = $10^{-2.50}$ mol/L = 3.16 mmol/L, what is the pH of the solution?

(2) [2] pH = 14 - pOH = 14 - 2.5 = 11.5

PART B - Numerical Problems

6. Calculate the maximum air phase concentration in mg/l for the immiscible fluid tetrachloroethane ($C_2H_2Cl_4$) in a system in contact with air and water. The important properties are:

GMW	167.85 g/mol	solubility	2900 mg/l	Air
Vapour Pressure	5.0 mmHg	density	1.60 g/cm^3	Water
	0.667 kPa	log Kow	2.4	$C_2H_2Cl_4$
	0.00658 atm	Henry's law	2.63 mol/atm/L	

Drinking Water Standard 0.17 µg/L

$$H = C_a / C_w \quad K_{ow} = C_{oc} / C_w \quad K_{oc} = S_{org} / C_w \quad K_p = f_{oc} K_{oc} = C_s / C_w \quad BCF = C_f / C_w$$

$$H = 1 / RTK_H' \qquad R=0.082 \text{ L atm/mol/}^{o}\text{K} \qquad T = 293\ ^{o}\text{K}$$

(4) • under equilibrium conditions, the max. conc. in water is equal to the solubility limit

[2] $C_w = 2900$ mg/L

• use Henry's Law to partition between water and air.

[1] $H = \frac{C_a}{C_w}$

$C_a = HC_w$

$C_a = (0.0158)(2900)$

$C_a = 45.82$ mg/L

$H = \frac{1}{RTK_H'}$

$H = \frac{1}{(0.082)(293)(2.63)}$

$H = 0.0158$ (unitless)

[1] - using correct equations

7. Hydroponics is the growth of plants in liquid media without contact with soil. Estimate the mg/kg concentration of toluene in 20 kg of plants that are grown in 1000 L of water into which 100 grams of toluene has been accidentally spilled. Assume that chemical equilibration is the only bio-uptake mechanism at work, that chemical partitioning between plant material and animal fats is similar, that there is insignificant partitioning of toluene into the air, and that the volume of water displaced by the plants is negligible.

max C_w = 515 mg/L	$K_{ow(25°C)} = 10^{2.69} = 490$
log BCF = (0.85 log K_{ow}) - 0.70	(BCF in $\frac{\text{kg/kg plants}}{\text{kg/L water}}$)

(6) $\log BCF = (0.85 \log K_{ow}) - 0.7$

$\log BCF = (0.85 \log 10^{2.69}) - 0.7$

[1] $BCF = 38.59$

$M_T = M_s + M_w + M_g \rightarrow 0$

[1] $M_T = M_s + M_w$

$M_T = M_{plants} C_s + V_w C_w$

[1] $M_T = M_{plants} BCF C_w + V_w C_w$ $\qquad BCF = \frac{C_s}{C_w}$

$(100) = (20)(38.59)C_w + (1000)C_w$

[1] $C_w = 0.0564\ g/L$

[1] $BCF = \frac{C_s}{C_w}$

$C_s = BCF\ C_w$

$C_s = (38.59)(0.0564)$

$C_s = 2.178 \frac{g\ toluene}{kg\ plant}$

[1] $C_s = 2178\ mg/kg$

8. A single Completely Mixed Reactor with a detention time of 1 hour has a steady-state treatment efficiency of 80% for a waste. Calculate the detention time for a Plug Flow Reactor that will yield the same treatment efficiency. Assume the reaction is first order for both systems. Equations for this problem are:

$$V\frac{dc}{dt} = Qc_{in} - Qc - V\lambda c^n \quad \text{for CMR}$$

$$\frac{\partial c}{\partial t} = -v\frac{\partial c}{\partial x} - \lambda c^n \ \text{ yielding } \ c(x) = c_0 e^{-(x)\lambda/v} = c_0 e^{-\lambda t_0} \quad \text{for PFR}$$

[1] • CMR: steady-state → $\frac{dc}{\partial t} = 0$, first order reaction → $n=1$

(6) ∴ $0 = QC_{in} - QC - \forall\lambda C$

$0 = \frac{C_{in}}{t_0} - \frac{C}{t_0} - \lambda C$ ∴, $t_0 = 1\,hr$

[1] $0 = C_{in} - C - \lambda C$

$0 = C_{in} - C(1+\lambda)$

$\frac{C}{C_{in}} = \frac{1}{1+\lambda}$

[1] • 80% efficiency means $C_{out} = 20\% = 0.2$

• due to a clerical error we posted that 80% efficiency means $C_{out} = 80\% = 0.80$, thus for this QUIZ only we will accept both interpretations

correct

$(0.2) = \frac{1}{1+\lambda}$

$\lambda = 4\,hr^{-1}$

• PFR: $C(x) = C_0 e^{-\lambda t_0}$

$\frac{C}{C_0} = e^{-\lambda t_0}$

$(0.2) = e^{-(4)t_0}$

$t_0 = 0.40\,hr$

incorrect

$(0.8) = \frac{1}{1+\lambda}$

$\lambda = 0.25\,hr^{-1}$

• PFR: $C(x) = C_0 e^{-\lambda t_0}$

$\frac{C}{C_0} = e^{-\lambda t_0}$

$(0.8) = e^{-(0.25)t_0}$

$t_0 = 0.89\,hr$

← [1] → (λ step, both cases)

← [2] → (PFR step, both cases)

BONUS QUESTION

The first of two equal sized Completely Mixed Reactors in series receives a slug input of a conservative contaminant. Each tank has a theoretical detention time of 1 hour. At a time of 2.0 hours after the slug was introduced to the first tank, the effluent concentration from the second tank relative to the initial concentration (C_0) in the first tank is measured to be 0.24. Are the tanks behaving as ideal CMRs?

$$c_i = \frac{c_0}{(i-1)!}\frac{t^{i-1}}{t_0}e^{-t/t_0}$$

(3) • $i = 2$

$$C_2 = \frac{C_0}{((2)-1)!}\frac{t^{(2)-1}}{t_0}e^{-t/t_0}$$

[1] $C_2 = C_0 \frac{t}{t_0} e^{-t/t_0}$

• $t_0 = 1\,hr$, $t = 2\,hr$

$$\frac{C_2}{C_0} = \frac{(2)}{(1)} e^{-(2)/(1)}$$

$$\frac{C_2}{C_0} = 0.27$$

[2] • measured concentration is 0.24

→ $0.24 \neq 0.27$, ∴ the tanks are not behaving as ideal CMRs