

FINAL EXAMINATION

Student Name: _____

This is a closed book final examination. Please use the paper provided for your answers and discussions or explanations.

<u>Question No.</u>	<u>Points</u>	<u>Score</u>
1.	25	_____
2.	15	_____
3.	15	_____
4.	25	_____
5.	25	_____
6.	15	_____
7.	35	_____
8.	15	_____
Total	170	_____

Exam Score/grade:

Course Score/grade:

Comments:

FINAL EXAMINATION

1. (25 pts) Distribution of organic chemicals and effect on engineering treatment technologies. Consider that the concentration of PAHs is increased in an octanol:water system as a result of additional contamination.

- (a) What is your prediction of the relative change of the value of K_{ow} ? **Explain**
- (b) As the concentration of PAHs is increased in the octanol:water system (not beyond the aqueous solubility) will Pump and Treat Technology be more applicable? **Explain.** Consider that the class of PCB compounds is added to the octanol:water system with PAHs
- (c) What is your prediction of the K_{ow} values for PAHs when PCBs are added? **Explain.**
- (d) Would the addition of PCB contaminants change the potential applicability of Pump and Treat Technology for PAHs in this system? **Explain.**
- (e) What is your prediction with regard to the solubility of benzo(b)fluoranthene and toluene in octanol, that is, which chemical would be predicted to have greater solubility in octanol and greater removal in NAPL recovery? **Explain** your answer and reasoning.

2. (15 pts) This question addresses sorption as discussed in Chapter 2, and conclusions with regard to contaminated site characterization. The value of the Freundlich exponential term, $1/n$, is often assumed to be one with nonpolar species. If the assumption is made that the value of $1/n=1$, and the value of $1/n$ is **actually greater than 1**, will an estimate of sorption underestimate or overestimate sorption & the effect of Pump & Treat Technology? (a) **Explain why, and (b) illustrate with a graph.**

3. (15 pts) Human exposure and phase control/management. Consider an “evaluative environment” contaminated with 1,300 grams Trichloroethylene (TCE) in a total environment volume of 1,000,000 cubic meters. Use Fugacity analysis for characterization and problem definition.

Given:

- a. The relative volumes of air, water, soil, and NAPL phases are assumed to be 0%, 30%, 70%, and 0%, respectively
- b. Soil organic carbon content = 0.5% in the aquifer soil phase; soil $\rho_b = 1.4$ gm/cc

Find:

- a. Calculate the percent distribution of TCE in each phase
- b. Calculate the mass, in grams, of TCE in each phase
- c. Determine the concentration of TCE in the water (aquifer) phase
- d. Does the aquifer phase concentration exceed the MCL for TCE?
- e. Calculate the mass of TCE that would be consumed in one day through ingesting 2 liters of water and divide by a 70-kilogram person to determine the daily dose.

4. (25 pts) TCE biodegradation using methanotrophic cooxidation. If the TCE in the aquifer were to be treated using the above process, calculate the following engineering parameters for accomplishing bioremediation:

- (a) describe the engineering process of methanotrophic cooxidation of TCE.
- (b) calculate the stoichiometric equation for TCE cooxidation taking into account oxygen and nutrient requirements and biomass production (use ammonium as the nutrient)
- (c) how does the methane concentration affect the rate and extent of TCE cooxidation?
- (d) What are the products of methanotrophic cooxidation of TCE?

5. (25 pts) Consider that some person takes a shower using the aquifer water described in Problem 3 above. **You should know the temperature of the water in a typical shower scenario, duration, and volume of water used; this was given in a previous class home-work problem, with instructions to study homework as preparation for the exam.**

- Calculate the mass of TCE in the water phase in one shower episode
- Calculate the mass of TCE in the vapor phase in one shower episode
- If the gas phase in the shower were evenly contaminated with the TCE, evaluate the amount (in grams) of TCE that would be taken in through inhalation in the air phase into the lungs
- Calculate the amount (grams) that would be exposed on the surface of the skin in the water phase in the shower scenario.

6. (15 pts) Given: Unsaturated flow conditions and measurements of soil moisture with time to a depth of 150 cm from the soil surface. Values for moisture content (θ) with depth and time are provided in the table below. **Show calculations for site characterization.**

<u>Time (hr)</u>	<u>Depth (cm)</u>	<u>Moisture, θ (cc/cc)</u>
0	0 - 50	0.21
0	50-100	0.20
20	0 - 50	0.20
20	50-100	0.18

- Find:
- Flux (Darcy) from the land surface to a depth of 100 cm.
 - Seepage velocity through the 100 cm depth.
 - Time (days) for water to reach the ground water.
 - With toluene present in the water within a soil matrix with a bulk density of 1.3 gm/cc and an organic carbon content of 1.3%, find the time (days) required for toluene to reach the ground water.

7. (35 pts) Design of a Prepared-Bed Bioremediation System

Diffusivity of oxygen in soil is given below for soil taken from a prepared-bed system.

<u>DGs (cm²/min)</u>	<u>Moisture Content by weight (%)</u>
3.6	0%
3.0	10%
1.3	15%

An equation based on Fick's law combined with continuity of mass can be used in the design of prepared-bed soil bioremediation systems:

$$\frac{2 D_Gs (C_o - C_G)}{R} = L^2$$

where D_{GS} is the soil diffusivity coefficient, C_G is the lower limit of allowable oxygen in soil (% oxygen) for aerobic biodegradation, C_o is the atmospheric O_2 concentration by volume, R is the rate of oxygen utilization within the contaminated soil, and L is the soil depth. The value of R must be determined for the specific soil. A typical value for R for newly applied contaminated soil is $1 \times 10^{-2} \%O_2/\text{min}$. Use the following boundary conditions for the design of a prepared-bed:

O_2 uptake rate (R) (% O_2 /min) = constant	$0 \leq x \leq L$
Soil % O_2 = Surface % O_2	$x = 0$
$dC_G/dx = 0$	$x = L$
Soil gas diffusivity (D_{GS}) = constant	$0 \leq x \leq L$

Determine:

- (1) The diffusivity of O_2 in air (cm^2/min)
- (2) Design the depth of a lift of soil that can be added to the bed and undergo aerobic biodegradation if the soil is maintained at 80% of field capacity. Moisture content (% by weight) at 15 bar is 5.5% and at 1/3 bar is 12.5%.
- (3) Determine the sensitivity of the depth of a lift to: (1) moisture content, and (2) the value of R. Use values of R that have been experimentally determined for Soil Bioventing. You design a graph or more than one graph to illustrate the effects of the variables moisture content and R on the depth of a lift. Think carefully about your graph.
- (4) What additional factors, besides moisture content, would affect the value of D_{GS} within a contaminated soil system treated by prepared-bed bioremediation or soil bioventing? Be specific and support your answer with references and logic.

8. (15 pts) Summarize one topic below, but you **cannot** summarize the topic that you presented in class. (1) Reactive Walls, (2) Thermal Processes (steam flushing, hot air flushing, resistance heating), (3) Thermal Processes (radio frequency heating, thermal desorption, vitrification), (4) fracturing, (5) air sparging, or electrokinetics.

POSSIBLY USEFUL INFORMATION

$$v = m_{\max} [S] / (K_s + [S])$$

$$Y_n = Y_m (0.1 + 0.8e^{-bt})$$

$$u_{\max} = km Y_m$$

$$dS/dt = -[(kmXS) / (S+K_s)]$$

molar volume = molecular weight/density

density of octanol = 0.8 gm/cc

$$\log K = -\log S_w - \log V_o^*$$

θ_m = water weight/ soil dry weight

θ_v = volume of water/ soil volume

ρ_b = soil dry weight/ soil volume

$$P = 1 - (\rho_b / \rho_p)$$

$$\partial\theta/\partial t = \partial J/\partial z$$

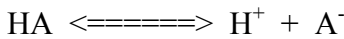
$$J = \int_0^z (\partial\theta/\partial t) dz$$

$$J = K(\theta) dh/dz$$

$$v = J/\theta = [K(\theta)/\theta] [dh/dz]$$

$$\partial\theta/\partial t = \partial[K(\theta) dh/dz]/\partial z$$

$$v = I/\theta$$



$$pK_a = \frac{[H^+][A^-]}{[HA]}$$

$$(fs)_t = (fs)_{\max} (0.2 + 0.8e^{-bt})$$

$$Y_m = (fs)_{\max} / (g/h)$$

$$S_{\min} = K_s[b/(u_{\max}-b)] = K_s[b/(Y_m k m - b)]$$

$$R = R_d + f_e R_a + f_s R_c$$

$$R = 1 + (\rho_b K_d)/\theta$$

K_d = Soil Concentration/Water Concentration

$$K_d = K_{oc} f_{oc}$$

$$Z_a = 1/RT = 4 \times 10^{-4} \text{ mol/m}^3 \text{ -Pa}$$

$$Z_w = 1/H$$

$$Z_s = K_d \rho_b Z_w$$

$$Z_o = Z_w K_{ow}$$

$$C_i = f_i Z_i$$

$$m_i = C_i V_i = f_i Z_i V_i$$

$$f = M/\sum Z_i V_i$$

$$R = V_w/V_p$$

$$L_2 = \frac{2 DG_s (C_o - C_G)}{R}$$

$$1 \text{ atm} = 10^5 \text{ Pa} = 760 \text{ mm Hg}$$

$$\log K = -\log S_w - \log V_o^* - \log \gamma_o^* - \log (\gamma_w/\gamma_w^*)$$

$$C_s = K_f C_w^{1/n}$$

$$(d \ln P)/dT = \Delta H_v/RT^2$$

$$R = 1.9872 \text{ cal mol}^{-1} \text{ K}^{-1};$$

$$\Delta H_v = 8,315 \text{ cal/mole for TCE; TCE mol.Wt.}=131.5$$

wilting point = water content at which loss of water by evapotranspiration exceeds ability of plants to extract water from soil.

available water = water considered available to plants

field capacity = water held by soil after gravity has drained away the water from a saturated soil