1.34 WASTE CONTAINMENT AND SITE REMEDIATION TECHNOLOGY
TAKE-HOME MID-TERM EXAM
DUE FRIDAY APRIL 2, 2004 AT 9:30 AM

This is an open-book exam, but the work should be yours alone. Please do not work with others on this exam.

SHORT ANSWER QUESTIONS (5 points each, 30 points total)

1. Bis(2-ethylhexyl)phthalate (BEHP) has the following properties:
    Density – ρ = 0.985 g/cm^3
    Henry's Law constant – H = 1.1 x 10^5 atm m^3/mol
    Octanol/water partition coefficient – log K_{OW} = 5
    Soil sorption coefficient – log K_{OC} = 5
    Solubility in water – C_W = 400 μg/L
    Vapor pressure – P° = 8 x 10^{-11} atm
    Based on this information, which of the following would you expect to be the most effective remedial option at a site contaminated by BEHP:
    a. soil-vapor extraction
    b. excavation and removal of contaminated soil
    c. ground-water pump and treat

2. A former metals plating shop is to be redeveloped but there is extensive contamination of the soils by heavy metals. Which of the following technologies would you expect to be most effective in remediating the soil contamination at this site:
    a. soil-vapor extraction
    b. solidification/stabilization
    c. bioremediation

3. Assess the likelihood of success of a soil vapor extraction system for a spill of gasoline. The spill occurred several months ago on a site underlain by fine sand.

4. At a site contaminated by TCE, the aquifer deposits consist of medium sand. The water-table gradient is approximately 0.007. A permeable reactive barrier (PRB) of zero-valence iron has been proposed to be constructed at the downgradient property line to remediate the TCE in the ground water. Laboratory tests have shown that TCE has a half-life of 10 hours in the zero-valence iron that will purchased for this PRB. What thickness PRB is required to lower TCE from a concentration of 5,000 μg/L to the MCL value of 5 μg/L?

5.   Your site is contaminated by a mix of chemical contaminants, including nitrate, perchloroethylene, carbon tetrachloride, benzene, toluene, and petroleum hydrocarbons. The site is located downgradient of a landfill, and degradation of organic matter in the landfill leachate has removed the dissolved oxygen from the ground water. Which of the chemicals in the mix above would you expect to be biodegraded in these circumstances?

6.   You have completed an investigation at your site. You have found that all soil samples are uncontaminated but several ground-water samples are contaminated by methylene chloride at concentrations of a few parts per billion. Explain the apparent discrepancy between the clean soil and contaminated ground water.

QUANTITATIVE QUESTIONS (70 points total)

The following constants and unit conversions <u>may</u> be helpful for the following questions:

R = gas constant = 0.082 L-atm/(mol °K)
1 atm = 760 mm Hg = 1.013×10^6 g/(cm-sec^2)
ρ_{air} = 0.00123 g/cm^3
μ_{air} = 0.018 cP = 1.8×10^{-4} g/(cm-sec)
μ_{water} = 1.0 cP = 1.0×10^{-2} g/(cm-sec)
1 dyne = 1 g-cm/sec^2

The following properties of TCE may also be helpful for the following questions:

Density – ρ = 1.46 g/cm^3
Aqueous solubility – C_W = 1100 mg/L
Residual saturation – S_r = 0.2
Dynamic viscosity – μ = 0.56 centipoise
Interfacial tension with water – σ = 34.5 dyn/cm
Soil sorption coefficient – K_{OC} = 126 ml/g
Henry's Law constant – $H = 9.1 \times 10^{-3}$ atm-m^3/mole

7.   (20 points)
During site investigations of a former gas station, a soil sample was collected in unsaturated silt at 2 meters below ground surface. The water table is located at 4 meters below ground surface. A laboratory analysis of the soil sample for TCE found a concentration of 1 mg/kg in this sample. The owner states he never used TCE on the site and the soil must have been contaminated by the underlying ground water, which is contaminated by a neighboring business. If the measured TCE concentration in the ground water is 10,000 µg/L, show mathematically if it is a reasonable hypothesis that the soil was contaminated by the underlying ground water. You can assume steady-state conditions, that the soil has a porosity of 0.4, that the soil saturation is 0.25, that the bulk density of the soil is 1.65 g/mL, and that the soil fraction organic carbon

(f_{OC}) is 0.001. You can also assume that there is no soil gas advection or biodegradation within the vadose zone.

8. (30 points)
    A tank of TCE has ruptured, releasing 1 cubic meter of TCE. The tank is surrounded by a containment dike of circular plan with a diameter of 2 meters. The TCE is held within the containment dike, but completely infiltrates into the underlying sandy soil. The geologic profile consists of the following: 3 meters of medium sand overlying a 10-cm layer of weathered clay which in turn overlies a sand and gravel aquifer. The clay layer is fractured by numerous large linear fractures. The typical fracture width is 20 micron. The water table is one meter below ground surface. Assume a soil porosity of 0.25 for the medium sand.

    Please answer the following questions:
    a. Does TCE DNAPL reach the clay layer?
    b. Does TCE DNAPL reach the underlying sand and gravel aquifer?

9. (20 points)
    The spill described in Question 8 has raised concerns that the ground water flowing past the DNAPL could become contaminated if the DNAPL penetrates the clay. There is a drinking water well 200 m directly downgradient of the spill. Site investigations have shown the water-table gradient is 0.0025, the hydraulic conductivity of the sand and gravel aquifer is 0.1 cm/s, the bulk density of the soils from the sand and gravel aquifer is 1.6 g/cm^3, and the fraction organic content (f_{OC}) of the soils from the sand and gravel aquifer is 0.005. Assume that the DNAPL penetrates the clay, that the ground water is in direct contact with TCE DNAPL, that TCE does not degrade in the ground water, and that flow is essentially one-dimensional. It would take about one year after the spill to get a remedial system in place. Would the concentration of TCE at the downgradient well likely exceed the drinking water MCL of 5 ppb for TCE within that time?