CEV426 Environmental Remediation
Spring 2017
MIDTERM EXAM
08.04.2017
(60 minutes)

Student ID# :
Name :

Please read and sign the below statement:

I have read and understood the exam conduct rules of the Faculty of Engineering before starting my exam.

Signature:

CHEMICAL PROPERTIES YOU MAY NEED:

Chemical	Molecular weight (g/mole)	Density (g/cm^3)	Saturated Vapor Pressure (atm)	Water Solubility (mg/L)	Henry's law constant (dimensionless)	log K_{ow}
Benzene	78	0.88	0.125	1780	0.23	2.13
Toluene	92	0.87	0.037	515	0.28	2.69

TABLE 3-4 The Complementary Error Function[a]

x	erfc(x)	x	erfc(x)
0	1.0		
0.05	0.943628	1.1	0.119795
0.1	0.887537	1.2	0.089686
0.15	0.832004	1.3	0.065992
0.2	0.777297	1.4	0.047715
0.25	0.723674	1.5	0.033895
0.3	0.671373	1.6	0.023652
0.35	0.620618	1.7	0.016210
0.4	0.571608	1.8	0.010909
0.45	0.524518	1.9	0.007210
0.5	0.479500	2.0	0.004678
0.55	0.436677	2.1	0.002979
0.6	0.396144	2.2	0.001863
0.65	0.357971	2.3	0.001143
0.7	0.322199	2.4	0.000689
0.75	0.288844	2.5	0.000407
0.8	0.257899	2.6	0.000236
0.85	0.229332	2.7	0.000134
0.9	0.203092	2.8	0.000075
0.95	0.179109	2.9	0.000041
1.0	0.157299	3.0	0.000022

$$\text{erfc}(x) = 1 - (2/\sqrt{\pi})\int_0^x e^{-\epsilon^2} d\epsilon$$
$$\text{erfc}(-x) = 2 - \text{erfc}(x)$$

[a]Adapted from Freeze and Cherry (1979).

Question 1 (10%)
What is the importance and purpose of conducting site assessment (or site characterization) in a typical soil and/or groundwater remediation project? When does a site assessment should include remedial investigation? What kind of data is collected during remedial investigation?

Question 2 (20%)
Solid waste containing a high concentration of chloride ion is placed directly on the clay liner of a landfill.
Assume that the solid waste and the clay are both saturated, and there is no fluid flow through the clay liner. Also, assume that the concentration of chloride in the leachate contained in the solid waste is much greater than the concentration of chloride in the pore water of the clay liner.
Provide a conservative estimate of the value of the concentration of chloride at the bottom of the clay liner after 100 years.
Use the following information in your calculations:
Concentration of chloride in the leachate = 100 mg/L.
The effective diffusion rate of chloride in pore water of the clay liner = 5×10^{-10} m^2/s.
The thickness of the clay liner = 5 m.

Question 3 (10%)
What is a NAPL?
Provide the name of a common contaminant or contaminant mixture that may form a NAPL in the subsurface.

Question 4 (20%)
A confined aquifer is 33 m thick and 7 km wide. Two observation wells are located 1.2 km apart in the direction of flow. The head in well 1 is 97.5 m and in well 2 it is 89.0 m. The hydraulic conductivity is 1.2 m/d. Aquifer porosity is 0.4 m. Estimate:

a) The Darcy velocity (specific discharge) of the groundwater in the aquifer.
b) The seepage velocity (average linear velocity) of the groundwater in the aquifer.
c) The total daily flow of water through the aquifer.

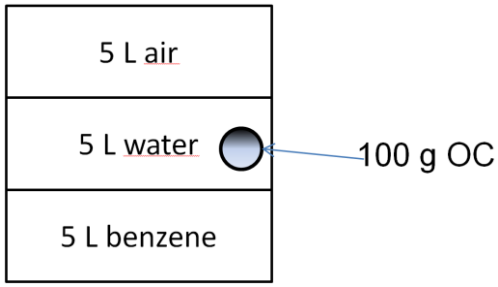
Question 5 (20%)

Determine the mass of toluene present in each of the following media. Which media contains the largest amount of toluene?

a) 5000 m^3 water containing 5 ppm toluene.
b) 5000 m^3 soil (total bulk density = 1800 kg/m^3) with 5 ppm of toluene.
c) An empty warehouse (indoor space = 5000 m^3) with 5 ppmV toluene in air (You may assume that molar volume of gases at the warehouse conditions is 24.5 L.)

Question 6 (20%)

If 100 g organic carbon (OC) is included in a waste container that contains 5 L of air, 5 L of water and 5 L of benzene, as shown below, what is the maximum concentration of benzene in the OC?



Question 7(5%)
What is transmissivity? Select the proper definition below.

a) A geologic unit that can store and transmit water at rates fast enough to supply reasonable amounts to wells.
b) The development and implementation of strategies to clean up (remediate) the environment by removing the hazardous contamination.
c) The amount of water that can be transmitted horizontally by the entire saturated thickness of the aquifer under a hydraulic gradient of one.
d) The ratio of the concentrations of a chemical in two different phases under equilibrium conditions.
e) A measure of the effect of the shape of the flowpath followed by water molecules in a porous media.

Question 8 (20%)
A well is located in an aquifer with a conductivity of 14.9 m/d and a storativity of 0.0051. The aquifer is 20.1 m thick and is pumped at a rate of 2725 m^3/d. What is the drawdown at a distance of 7.0 m from the well after 1 day of pumping?

SOME EQUATIONS YOU MAY NEED:

Relationship between K_{oc} and K_{ow}

$K_{oc} = 0.63K_{ow}$	K_{oc} : Organic carbon partition coefficient (L/kg) K_{ow} : Octanol-water partition coefficient (L/kg)

Darcy's Law

$Q = -KA\frac{dh}{dl}$	Q : volumetric discharge (L^3/T) K : hydraulic conductivity (L/T) A : cross-sectional area (L^2) dh/dl : gradient of hydraulic head (L/L)

Theis Equation (**Nonequilibrium** Equation) for Flow in a Completely Confined Aquifer

$$h_0 - h = \frac{Q}{4\pi T} \times W(u)$$

W(u) : Well function

$$W(u) = -0.5772 - \ln u + u - \frac{u^2}{2 \cdot 2!} + \frac{u^3}{3 \cdot 3!} - \frac{u^4}{4 \cdot 4!} + \ldots$$

$$u = \frac{r^2 S}{4Tt}$$

for $u < 0.1$: $W(u) = -0.5772 - \ln u$

Q : Constant pumping rate (L^3/T; m^3/d)
h : Hydraulic head at distance r at time t (L; m)
h_0 : Initial hydraulic head (L; m)
$h_0 - h$: Drawdown (L; m)
T : Aquifer transmissivity (L^2/T; m^2/d)
t : Time since pumping began (T; d)
r : Radial distance from the pumping well (L; m)
S : Aquifer storativity (-)

1-D Diffusive Transport Equation for Porous Media

$$\frac{\partial C}{\partial t} = D^* \frac{\partial^2 C}{\partial x^2}$$

C : Concentration of the diffusing chemical (M/L^3)
D^* : Effective diffusion coefficient in porous media (L^2/T)
x : The coordinate specifying the direction of transport (L)

Solution for the specified initial (I.C.) and boundary conditions (B.C.):

I.C.:
$C(x = 0, t = 0) = C_0$
$C(x > 0, t = 0) = 0$

B.C.:
$C(x = 0, t) = C_0$

$$C(x,t) = C_0 \text{erfc}\left(\frac{x}{2\left(D^* t\right)^{0.5}}\right)$$

C_0 : the original concentration, which remains a constant (M/L^3)
erfc : the complementary error function