CEV426 Environmental Remediation
Spring 2016
MIDTERM EXAM
02.04.2016
(60 minutes)

Student ID# :
Name :

Please read and sign the below statement:

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

Signature:

Question 1 (10%)
Match the term on the left with the appropriate definition on the right.

Terms
Transmissivity
Water solubility
Aquifer
Tortuosity
Vapor pressure

Definitions
A geologic unit that can store and transmit water at rates fast enough to supply reasonable amounts to wells.
The ratio of the concentrations of a chemical in two different phases under equilibrium conditions.
The pressure exerted by the vapors of a pure liquid (or solid) chemical at saturation conditions at a certain environmental temperature.
The surface at which pore water pressure in a porous medium is equal to atmospheric pressure.
The amount of water that can be transmitted horizontally by the entire saturated thickness of the aquifer under a hydraulic gradient of one.
Non-aqueous phase liquid.
The concentration of a chemical dissolved in water when that water is both in contact and at equilibrium with the pure chemical.
The development and implementation of strategies to clean up (remediate) the environment by removing the hazardous contamination.
A measure of the effect of the shape of the flowpath followed by water molecules in a porous media.
The volume of water that a permeable unit will absorb or expel from storage per unit surface area per unit change in head.

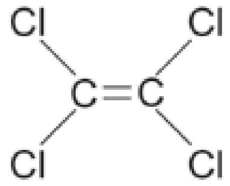
Question 2 (10%)
Give a list of data items that may be collected through remedial investigation activities.

Question 3 (20%)
The subsurface of a site is contaminated with tetrachloroethylene (PCE). A recent soil vapor survey indicates that the soil vapor contained 900 ppmV of PCE.

a. Estimate the PCE concentration in the soil moisture.
b. Estimate the PCE concentration adsorbed on the soil solids.

The soil contains 1% of organic carbon. Assume the adsorption follows a linear model.
This relationship can be used to estimate K_{oc} (L/kg): $K_{oc} = 0.63\ K_{ow}$
(You may assume that molar volume of gases at the site conditions is 24.05 L.)

Tetrachloroethylene (PCE)



Chemical Properties

Chemical	**Molecular weight (g/mole)**	**Henry's law constant (dimensionless)**	**log K_{ow}**
Tetrachloroethylene (PCE)	166	0.34	2.88

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 of the groundwater in the aquifer.
b. The seepage velocity of the groundwater in the aquifer.
c. The total daily flow of water through the aquifer.

Question 5 (20%)
Use the following information to estimate the hydraulic conductivity of a confined aquifer:

- Aquifer thickness = 9.1 m
- Well diameter = 0.1 m
- Well perforation = fully penetrating
- Groundwater extraction rate = 100 m^3/day
- The original piezometric surface elevation = 24.4 m
- Steady-state drawdown
  = 60 cm observed in a monitoring well 1.5 m from the pumping well
  = 40 cm observed in a monitoring well 6 m from the pumping well

Question 6 (20%)

A column experiment is set up in the laboratory. Sand is packed into a cylindrical column, 1.5 m in length and 10 cm in diameter; water flows through the column with a seepage velocity of 0.5 m/hr. Porosity is 0.3. Five miligrams of salt are injected into the column (a pulse injection). Hydrodynamic dispersion coefficient is estimated to be 5×10^{-4} m^2/hr.
After 2 hours, where (at what distance down the column) will you see the maximum salt concentration? What is this maximum concentration?

SOME EQUATIONS YOU MAY NEED:

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)

Steady-State Groundwater Well Equations

Confined Aquifer	
$$h_2 - h_1 = \frac{Q}{2\pi T}\ln\left(\frac{r_2}{r_1}\right)$$	T is aquifer transmissivity (L^2/T; ft^2/d or m^2/d) Q is pumping rate (L^3/T; ft^3/d or m^3/d) h_1 is head at distance r_1 from the pumping well (L; ft or m) h_2 is head at distance r_2 from the pumping well (L; ft or m)
Unconfined Aquifer	
$$b_2^2 - b_1^2 = \frac{Q}{\pi K}\ln\left(\frac{r_2}{r_1}\right)$$	K is hydraulic conductivity (L/T; ft/d or m/d) Q is pumping rate (L^3/T; ft^3/d or m^3/d) b_1 is saturated thickness at distance r_1 from the pumping well (L; ft or m) b_2 is saturated thickness at distance r_2 from the pumping well (L; ft or m)

Solution to the 1-D Advective-Dispersive Transport Equation with First-Order Decay

Pulse Input	
$$C(x,t) = \frac{M}{n\sqrt{4\pi D_L t}} e^{-(x-vt)^2/(4D_L t)} e^{-kt}$$	C : Concentration (M/L^3) M : Mass input per unit area (M/L^2) x : Distance (L) D_L : Longitudinal Fickian transport coefficient (L^2/T) n : Porosity (L^3/L^3) t : Time (T) v : Seepage velocity (L/T) k : First-order decay rate coefficient (T^{-1})