CEV426 Environmental Remediation
Spring 2015
FINAL EXAM
29.05.2015
(75 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%)
Fill in the blanks. Use one of the candidate terms given below for each blank.

Fick's second law
retardation
advection
tortuosity
soil-vapor extraction
LNAPL
DNAPL
groundwater cut off wall
groundwater extraction well
dispersion
gas
dissolved
sorbed
pump-and-treat

If a landfill is constructed with an excavation that extends below the water table, groundwater can flow through the waste and create leachate. Such a landfill can be surrounded by a …………………………………………... to divert groundwater flow from passing through the waste.

In a pump-and-treat system, the greater the distribution coefficient (K_d), the more slowly the …………………………….. phase will be released and the longer it will take to remediate the aquifer.

Soils contaminated with volatile organic compounds can be remediated with …………………………………. . The process is analogous to …………………………….. for groundwater.

In porous media, diffusion cannot proceed as fast as it can in water, because the ions must follow longer pathways as they travel around mineral grains. …………………………….. is a measure of the effect of the shape of the flowpath followed by water molecules in a porous media.

Question 2 (6%)
In an in-situ groundwater bioremediation project, how would you enhance the rate of biodegradation of pollutants in the aquifer?

Question 3 (28%)
Groundwater is contaminated with gasoline. The average dissolved gasoline concentration of the groundwater samples is 20 mg/L. In situ bioremediation is being considered for aquifer restoration. The aquifer has the following characteristics:

- Porosity = 0.35
- Organic content = 0.02
- Bulk density of the aquifer materials = 1.8 g/cm^3

Determine:

a) Contaminant concentration adsorbed to the aquifer solids assuming equilibrium partitioning.
b) Total contaminant mass in 1 m^3 of aquifer.
c) For 1 m^3 of aquifer, the number of moles of nitrogen (N) and phosphorus (P) needed to support the biodegradation of the contaminants.

(Optimal molar C:N:P ratio is 100:10:1).
(Data for gasoline is not available. You may use the data of one of the common components in gasoline, such as toluene.)

Question 4 (28%)

A water table (unconfined) aquifer is 12.2 m thick. Groundwater is being extracted from a 0.1- m diameter fully penetrating well. The pumping rate is 0.15 m^3/min. The aquifer is relatively sandy with a hydraulic conductivity of 8.1 m/day. Steady-state drawdown of 1.5 m is observed in a monitoring well at 3.0 m from the pumping well.

Estimate:

a) The drawdown in the pumping well
b) The radius of influence of the pumping well

Question 5 (28%)
A subsurface is contaminated by a benzene spill. The subsurface has the following characteristics:

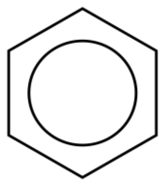
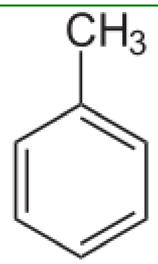
- Porosity = 0.35
- Organic content = 0.03
- Water saturation = 45%
- Bulk density of soil = 1.7 g/cm^3

a) What would be the saturated soil-air concentration if free-product phase is present?
b) What would be the saturated soil-water concentration if free-product phase is present?
c) What would be the saturated soil-solids concentration if free-product phase is present?
d) What would be the maximum contaminant concentration in soil (in mg / kg) if the free-product phase of benzene is absent?

(You may assume that molar volume of gases at the site conditions is 24.5 L.)

Chemical Properties

Chemical	Molecular Formula	Molecular weight (g/mole)	Henry's law constant (dimensionless)	log K_{ow}	Saturated Vapor Pressure (atm)
Benzene	C_6H_6	78	0.23	2.13	0.125
Toluene	C_7H_8	92	0.28	2.73	0.029

Benzene	Toluene
	

SOME EQUATIONS YOU MAY NEED:

Relationship between K_{oc} and K_{ow}

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

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)