CEV426 Environmental Remediation
Spring 2016
FINAL EXAM
30.05.2015
(75 minutes)

Student ID# :
Name :

Please read and sign the below statement:

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

Signature:

Question 1 (12%)
Fill in the blanks. Use one of the candidate terms given below for each blank.

retardation
adsorption
dissolution
volatilization
advection
dispersion
biodegradation
vapor pressure
solubility
octanol-water partition coefficient
Henry's law constant

Volatile organic compounds in a vadose zone may be present in four phases:
(1) in the soil moisture due to **…………………………..**,
(2) on the soil grain surface due to **…………………………..**,
(3) in the pore void due to **…………………………..**,
(4) as the free product.
If the free product phase is present, the vapor concentration in the pore void can be estimated from Raoult's law using the compound's **…………………………..** and mole fraction.

During the transport of contaminants in an aquifer, **…………………………..** delays the advance of the solute front, whereas **…………………………..** reduces the peak value.

Question 2 (5%)
Contaminants that have been in the ground for a long period of time are able to diffuse into the less permeable zones of porous media aquifers and into the bedrock matrix of fractured rock aquifers.
Pump-and-treat systems are inefficient in removing these contaminants. Why?

Question 3 (18%)

For an aquifer solid with a bulk density of 2 g/cm^3 containing 0.5% organic carbon, estimate the retardation factor for the common polycyclic aromatic hydrocarbon (PAH) naphthalene ($C_{10}H_8$), used in mothballs.

If the porosity of the aquifer is 0.24, the hydraulic conductivity is 10^{-3} cm/sec, and the hydraulic gradient is 0.001, how fast will a plume of naphthalene travel?

Question 4 (30%)
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 = 1.6 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 mass of oxygen required to support biodegradation of intruding gasoline.

(Assume 3.08 g of oxygen is required for the complete biodegradation of 1 g of gasoline.)
(Data for gasoline is not available. You may use the data of one of the common components in gasoline, such as toluene.)

Question 5 (15%)

A community is installing a new well in a regionally confined aquifer with a transmissivity of 150 m^2/day and a storativity of 0.0004. The planned pumping rate is 2000 m^3/day. Compute the theoretical drawdown caused by the new well after 30 days of continuous pumping at 1000 m distance.

Question 6 (30%)

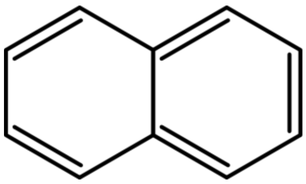
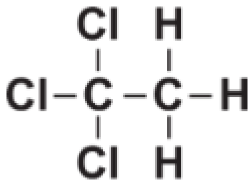
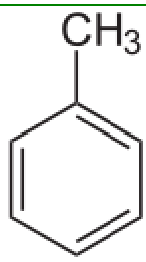
A subsurface is contaminated by a spill of 1,1,1-trichloroethane (1,1,1-TCA).
The average TCA concentration of the soil samples, taken from the impacted zone is 2000 mg/kg, and no free-product phase is present.
The subsurface has the following characteristics:

- Porosity = 0.4
- Organic content in soil = 0.02
- Degree of water saturation = 30%
- Dry bulk density of soil = 1.6 g/cm^3
- Total bulk density of soil = 1.8 g/cm^3

Soil-vapor extraction is being considered for the remediation of the impacted zone. Estimate the extracted soil-vapor concentration at the start of the remediation project. Report the soil-vapor concentration in units of both **mg/L** and **ppmV**.

CHEMICAL PROPERTIES YOU MAY NEED:

Chemical	Molecular Formula	Molecular weight (g/mole)	Henry's law constant (dimensionless)	log K_{ow}	Saturated Vapor Pressure (atm)
Naphthalene	$C_{10}H_8$	128	0.049	3.36	0.0003
Toluene	C_7H_8	92	0.28	2.69	0.037
1,1,1 TCA	$C_2H_3Cl_3$	133	0.77	2.48	0.13

Naphthalene	1,1,1 TCA	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)

Darcy's Law

$Q = -KA\dfrac{dh}{dl}$	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)

Retardation

$R = 1 + K_d \dfrac{\rho_b}{n}$	R : Retardation factor $\left[(M/L^3)/(M/L^3)\right]$ K_d : Distribution coefficient (L^3/M) ρ_b : Bulk density (M/L^3) n : Porosity (L^3/L^3)

SOME MORE EQUATIONS YOU MAY NEED:

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 (-)