Faculty of Engineering and Applied Science,
Engi 7718 – Environmental Geotechniques

Third Quiz , Open Notes — Instructor: Dr. C.A. Coles
Wednesday, 15 July 2009, 9:00 – 9:50 a.m.

There are 2 questions worth a total of 17 marks. Only non-programmable scientific calculators without text or graphics storage are permitted. Show all work.

Name:_____ Student ID:_____

1) Given the information provided below, indicate which Log K_{OW} values (3.15 and 4.88) and which boiling points (136°C and 404°) would be expected for each compound and explain why. (3 marks)
For a bonus mark match the chemical formulas ($C_{16}H_{10}$ and C_8H_{10}) and explain your answers.

	Pyrene	Ethyl benzene
Water solubility (mg/L)	0.148	152
Henry's Law constant (atm·m^3/mol)	1.87×10^{-5}	5.43×10^{-3}
Log K_{OW}	4.88	3.15
Boiling points (°C)	404	136
Chemical formula	$C_{16}H_{10}$	C_8H_{10}

Ethyl benzene has high Henry's law constant and is more volatile, enters the atmosphere more easily and would therefore have a lower boiling point

Ethyl benzene has a higher water solubility and greater preference for the aqueous phase and would have a lower log Kow.

Smaller molecular weight compounds are more easily moved between different phases and are usually more volatile.

2) A landfill will be cited on a naturally occurring clay layer that is 3 m thick. The maximum allowable head of leachate that can collect on top of the clay is 30 cm. The self diffusion coefficient for the clay is 10.2×10^{-10} m^2/s, the hydraulic conductivity of the clay is 1×10^{-10} m/s and the tortuosity is 0.6. The clay has a porosity of 50%, an average particle size is 0.003 mm, a dry density of 1.7 g/cm^3, a specific surface area of 40 m^2/g and contains 1.2% organic carbon. Some of the landfill leachate contains Carbofuran that has a Log K_{OW} of 1.62 and belongs to the insecticide and herbicide group for which the regression formula is: $\log K_{OC} = 1.029 \log K_{OW} - 0.18$.

a) Find the Peclet number for these conditions and indicate the type of transport predicted. (4 marks)

b) If the leachate migrating though the clay layer is controlled by diffusion and there is no retardation, when will the concentration ratio, C/C_0 equal 0.1? No interpolation from table is required. (4 marks)

c) What is the retardation factor for the Carbofuran component of the leachate? (6 marks)

2) $L = 3m$
$h = 0.3m$
$D_0 = 10.2 \times 10^{-10} m^2/s$
$K = 1 \times 10^{-10}$ m/s
$\tau = 0.6$
$n = 0.50$
$d = 0.003$ mm
$\rho_d = 1.7$ g/cm^3
$SSA = 40$ m^2/g
1.2% organic carbon = f_{OC}

Carbofuran
Log K_{ow} = 1.52

log K_{OC} = 1.029 log K_{ow} − 0.18

a) $Pe = \frac{V_s d}{D_0}$ $\quad D^* = \tau D_0$ $\quad V_s = \frac{Ki}{n}$

$i = \frac{0.3 + 3.0}{3.0} = 1.1$ $\quad$ 0.3m. / 3m

$V_s = \frac{Ki}{n} = 1 \times 10^{-10} \frac{m}{s} \times \frac{1.1}{0.5} = 2.2 \times 10^{-10} \frac{m}{s}$

$Pe = 2.2 \times 10^{-10} \frac{m}{s} \times \frac{3 \times 10^{-6} m}{10.2 \times 10^{-10} m^2} \frac{s}{} = 6.47 \times 10^{-7} << 0.01$

Therefore diffusion controls transport

b) $R = 1$

$\frac{C}{C_0} = 0.1 = \text{erfc}\left(\frac{x}{2\sqrt{D^* t}}\right)$

$D^* = D_0 \tau = 10.2 \times 10^{-10} \frac{m^2}{s} \times 0.6 = 6.12 \times 10^{-10} \frac{m^2}{s}$

convert to years: $6.12 \times 10^{-10} \frac{m^2}{s} \times 60 \times 60 \times 24 \times 365 \frac{s}{yr}$

$= 0.0193 \frac{m^2}{y}$

$$0.1 = erfc(\beta) \quad \therefore \beta = 1.16$$

$$\frac{3m}{2\sqrt{0.0193 \frac{m^2}{y}}\sqrt{t}} = 1.16$$

$$(\sqrt{t})^2 = \left(\frac{10.8}{1.16}\right)^2 = (9.31)^2 = 86.6 \text{ years.}$$

c) $R = 1 + \frac{\rho_d K_d}{n}$ $\qquad f^*_{oc} = \frac{SSA}{200 (K_{ow})^{0.84}}$

$K_d = K_{oc} \times f_{oc}$

$\log K_{oc} = 1.029 \log K_{ow} - 0.18$
$= 1.029 \times 1.62 - 0.18$
$= 1.487$

$K_{oc} = 30.69$
$K_{ow} = 41.69$

$f^*_{oc} = \frac{40}{200 (41.69)^{0.84}} = 8.71 \times 10^{-3} = 0.00871 < 0.012$
so regression eq. valid.

$K_d = K_{oc} \times f_{oc} = 30.69 \times 0.012 = 0.368$

$R = 1 + \frac{1.7 \times 0.368}{0.5} = 2.25$

2:38.