3. CERCLA authorizes two kinds of response actions (source: http://www.epa.gov/superfund/policy/cercla.htm):

- **Short-term removals**, where actions may be taken to address releases or threatened releases requiring prompt response.
- **Long-term remedial response actions**, that permanently and significantly reduce the dangers associated with releases or threats of releases of hazardous substances that are serious, but not immediately life threatening. These actions can be conducted only at sites listed on EPA’s National Priorities List (NPL).

5. Groundwater is contaminated with 300 µg/L (300 ppb) toluene. Assume the aquifer solids contain 1.5% organic carbon and that sorption is adequately described by a linear model. Estimate the mass of toluene sorbed to the solid material.

From Table 12.3b, the log $K_{OW}$ for toluene is 2.73. Use Equation 12.3 to estimate the soil distribution coefficient, $K_{SD}$.

$$K_{SD} = 6.3 \times 10^{-7} \times f_{oc} \times K_{OW} = 6.3 \times 10^{-7} \times (0.015) \times (10^{2.73}) = 5.08 \times 10^{-6} \frac{L}{mg}$$

$$K_{SD} = \left( 5.08 \times 10^{-6} \frac{L}{mg} \right) \left( \frac{10^6 mg}{L} \right) = 5.08 \frac{L}{kg}$$

Using Equation 12.2 that describes linear sorption and the $K_{SD}$ value obtained from Equation 12.3, determine the equilibrium toluene concentration sorbed to the solid phase in the aquifer.

$$s = K_{SD} C_L = \left( 5.08 \frac{L}{kg} \right) \left( 300 \frac{\mu g}{L} \right) \left( \frac{mg}{1000 \mu g} \right) = 1.52 \frac{mg \text{ toluene sorbed}}{kg \text{ soil}}$$

6. Results from a soil vapor study showed a soil vapor concentration for vinyl chloride of 1500 ppmv. Use Henry’s Law to estimate the surrounding liquid phase VC concentration.

Convert the volume based vapor phase concentration to a mass per unit volume basis. Assume system $T = 25^{\circ}C$. From Table 12.3a; $MW = 62.5$ and $k_{HA} = 3.35$.

$$\frac{\mu g}{m^3} = \frac{ppmv \times MW \times 10^3}{24.4} \quad (at \ 25^{\circ}C)$$
\[
\text{mg} \times \text{MW} \times 10^3 = 1500 \times 62.5 \times 10^3
\]
\[
= 3.84 \times 10^9 \mu g m^{-3} = 3.84 mg L^{-1}
\]

Using Henry’s Law to calculate the aqueous phase concentration,

\[
C_g = k_{H,A} C_L
\]

\[
C_L = \frac{C_g}{k_{H,A}} = \frac{3.83 \text{ mg L}^{-1}}{3.35} = 1.15 \text{ mg L}^{-1}
\]

7. A sample of moist soil having a wet weight of 1500 g and volume of 1000 cm\(^3\) was oven-dried and found to have a dry mass of 1150 g. Determine the soil: dry bulk density, porosity, and the volumetric water content. Assume a soil density of \(\rho_s = 2.65 \text{ g/cm}^3\).

From the problem statement, recognize that:

\(M_t = 1500 \text{ g}, M_s = 1150 \text{ g}, \text{ and } V_t = 1000 \text{ cm}^3\)

Knowing the soil density is \(\rho_s = 2.65 \text{ g/cm}^3\). And, given that the mass of the solid is 1150 g, the volume of the solid is \(V_s = (1150 \text{ g})/(2.65 \text{ g/cm}^3) = 434 \text{ cm}^3\).

Assume that the mass of the air is negligible, so \(M_a = 0\). The mass of the water present in the sample can be determined as: \(M_w = (1500 - 1150)\text{g} = 350 \text{ g}\). Assuming the density of water is 1 g/cm\(^3\), the volume of water in the sample is \(V_w = 350 \text{ cm}^3\).

Recognize that the total sample volume is \(V_t = 1000 \text{ cm}^3 = V_a + V_w + V_s\). Knowing the volumes of the water and solid phases, we can algebraically determine \(V_a = 216 \text{ cm}^3\).

With \(V_t = 1000 \text{ cm}^3\), \(V_w = 350 \text{ cm}^3\), \(V_s = 434 \text{ cm}^3\), and \(V_a = 216 \text{ cm}^3\), we can determine the unknown mass and volume soil relationships. Use Figure 12.3 and Table 12.4 to determine appropriate definitions and equations.

Dry bulk density = \(\rho_b = \frac{M_s}{V_t} = \frac{1150 \text{ g}}{1000 \text{ cm}^3} = 1.15 \text{ g cm}^{-3}\)

porosity = \(\eta = \frac{V_a}{V_t} = \frac{V_a + V_w}{V_t} = \frac{(216 + 350) \text{ cm}^3}{1000 \text{ cm}^3} = 0.566\)

volumetric water content = \(\Theta = \frac{V_w}{V_t} = \frac{350 \text{ cm}^3}{1000 \text{ cm}^3} = 0.35\)
8. Assume a leak in a 500-gal underground storage tank containing water contaminated with Aroclor® 1254 and acetone. Estimate how far each contaminant will travel in 1 year. Assume the following hydrogeologic characteristics:

Soil porosity = 0.45  
Hydraulic gradient = 0.06 ft/ft  
Fraction of organic content in the soil = 0.5%  
Aquifer conductivity = 0.0001 cm/s  
Acetone log \( K_{OW} = -0.23 \)

Use Equation 12.5 to calculate the Darcy velocity.

\[
q = K_c \frac{dh}{dL} = \left( 0.0001 \text{ cm/s} \right) \left( 0.06 \text{ ft/ft} \right) = 6 \times 10^{-6} \text{ cm/s}
\]

From Equation 12.6, the pore velocity can be estimated as:

\[
\nu = \frac{q}{\eta} = \frac{6 \times 10^{-6} \text{ cm/s}}{0.45} = 1.3 \times 10^{-5} \text{ cm/s}
\]

Find \( K_{OW} \) value for the PCB mixture in Table 12.3.

Develop a summary table for the compounds spilled.

<table>
<thead>
<tr>
<th>Compound</th>
<th>( K_{OW} )</th>
<th>( f_{OC} )</th>
<th>( K_{SD} ) (L/mg)</th>
<th>( R )</th>
<th>( \nu_p ) (cm/s)</th>
<th>Distance (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aroclor® 1254</td>
<td>10^{0.03}</td>
<td>0.005</td>
<td>3.38E-03</td>
<td>9,765</td>
<td>1.3E-09</td>
<td>0.04</td>
</tr>
<tr>
<td>Acetone</td>
<td>0.58</td>
<td>0.005</td>
<td>1.83E-09</td>
<td>1.005</td>
<td>1.3E-05</td>
<td>408</td>
</tr>
</tbody>
</table>

Calculate the \( K_{SD} \) for each compound using Equation 12.3. For example, the \( K_{SD} \) for Aroclor® 1254 is found as follows:

\[
K_{SD} = 6.3 \times 10^{-7} f_{OC} K_{OW} = \left( 6.3 \times 10^{-7} \right) \left( 0.005 \right) \left( 10^{0.03} \right) = 3.38 \times 10^{-3} \text{ L/mg}
\]

Use Equation 12.8 to determine the Retardation factor for each compound. The calculation is demonstrated with Aroclor® 1254.

\[
R = 1 + \frac{\rho_b}{\eta} K_{SD} = 1 + \left( \frac{1.3 \text{ g/ml}}{L} \right) \left( \frac{1000 \text{ ml}}{L} \right) \left( 3.38 \times 10^{-3} \text{ L/mg} \right) \left( \frac{1000 \text{ mg}}{g} \right) \left( \frac{0.45}{0.45} \right) = 9,765
\]

Relying on Equation 12.7, calculate the velocity of each contaminant. For Aroclor® 1254:
\[ v_p = \frac{v}{R} = \frac{1.3 \times 10^{-5} \text{ cm}}{9,765 \text{ s}} = 1.3 \times 10^{-9} \text{ cm/s} \]

Now, calculate the distance traveled in one year. Again, Aroclor® 1254 is used as an example:

\[ \text{distance} = v_p \times \text{time} \]

\[ \text{distance} = \left(1.3 \times 10^{-9} \frac{\text{cm}}{\text{s}}\right)(1\text{ yr})\left(\frac{365\text{ d}}{\text{ yr}}\right)\left(\frac{24\text{ hr}}{\text{ d}}\right)\left(\frac{60\text{ min}}{\text{ hr}}\right)\left(\frac{60\text{ s}}{\text{ min}}\right) = 0.04 \text{ cm} \]