Explanation of Example Problem

A 100 m^3 tanker containing a 100 mg/m^3 solution of 2,4-dinitotoluene wrecks and empties its entire contents above an aquifer. The cross-sectional area of the spill is 50 m^2. The aquifer has a porosity of 30 percent, a bulk density of 1.6 g/cm^3, a velocity of 10 m/yr, and a dispersion coefficient of 10 m^2/yr. The distribution coefficient of 2,4-dinitotoluene for this aquifer material has been measured to be 2.5 mL/g. 2,4-dinitotoluene biodegrades through a first order reaction at a rate of 0.693 yr^{-1}. How far and how fast will 2,4-dinitotoluene migrate through the aquifer?

Solution:

1. Calculate the retardation factor from the distribution coefficient.

$$R = 1 + \frac{\rho_b K_d}{n},$$

$$= 1 + \frac{\left(1.6\ \frac{g}{cm^3}\right)\left(2.5\ \frac{mL}{g}\right)}{0.3} = 14.33.$$

2. Correct the cross-sectional area of the spill site to the void volume rather than the total volume.

Cross-sectional area * porosity = $50m^2 \times 0.3 = 15\ m^2$.

3. Calculate the total mass of chlordane spilled.

Volume spilled * concentration of solution =

$$\left(100m^3\right)\left(1000\ \frac{mg}{m^3}\right) = 100{,}000\ mg \text{ or } 100\ g.$$

4. If necessary, calculate the first order degradation rate from the half-life.

$$-\frac{\ln 0.5}{t_{1/2}} = k = = -\frac{-0.693}{0.09625(yr)} = 0.693\ yr^{-1}.$$

5. Arrange data into proper units

groundwater velocity, v = 10 m/yr,
the retardation factor, R = 14.33,

the mass of contaminant, M = 100,000 mg
the dispersion coefficient, D = 10 m^2/yr,
the reaction rate constant, k = 0.693 yr^{-1}, and
the cross-sectional area, A = 15 m^2.

6. Input data into program and obtain graph.

7. Calculate the concentration 10 meters down gradient from the lagoon ten years after the input.

$$C(x,t) = \frac{M}{A * \sqrt{4\pi \frac{D}{R} t}} * e^{-\frac{\left(x - \left(\frac{v}{R}\right) * t\right)^2}{4\frac{D}{R} t} - kt}$$

$$= \frac{100{,}000\text{mg}}{15\text{m}^2 \sqrt{4\pi \left(\frac{10\frac{\text{m}^2}{\text{yr}}}{14.33}\right) * 10\text{yr}}} * e^{-\frac{\left(10\text{m} - \left(\frac{10\frac{\text{m}}{\text{yr}}}{14.33}\right)10\text{yr}\right)^2}{4 * \left(\frac{10\frac{\text{m}^2}{\text{yr}}}{14.33}\right) * 10\text{yr}} - \left(0.693\frac{1}{\text{yr}}\right)10\text{yr}}$$

= 1,971 mg/m^3 or 1.971 mg/L 2,4-dinitotoluene.