

## RETARDATION FACTOR

Retardation factor,  $R_f$ , for a particular chemical species is the ratio of solution velocity and species velocity or in other words the ratio between the rate of groundwater movement and rate of contaminant movement.  $R_f$  is a bulk property of the entire system combining all the effects of solution chemistry, soil properties and chemical reactions. Both ion exchange and sorption are the processes that tend to remove specific species from solution and retard their migration through the subsurface. Sorption refers to the process where a species leaves the solution and is adsorbed into the surface of a solid resulting in an increase in the concentration of the contaminant in the soil and a relatively lower concentration in the water. Ion exchange is important in clay minerals that are composed of layered sheets, which can have interlayer species such as  $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{K}^+$ , and  $\text{H}_2\text{O}$ . These can exchange with any number of metal ions.

### Laboratory Procedure

$R_f$  can be determined by column flow studies in the laboratory where representative, site specific, soil and separate phase contaminants are used. Solutions of varying concentrations are prepared and passed through a soil column. At each equilibrium stage, the effluent is analyzed and the amount adsorbed on the soil is calculated. Plotting the solute concentration  $C$ , against the mass adsorbed  $C^*$ , on log-log scale will yield a straight-line function and under these conditions the derivative of  $C^*$ , with respect to  $C$ , yields the relationship

$$dC^* / dC = K_d$$

$$\text{or: } K_d = \text{slope of } C^* \text{ vs } C$$

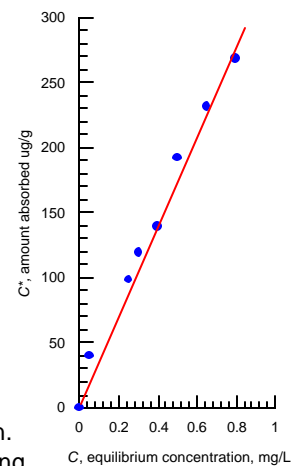
where  $K_d$  is the distribution coefficient.  $K_d$  can be used to calculate the retardation factor of the solute front as it passes through the soil by

$$\text{Retardation Factor} = 1 + (\rho_b/\theta) (K_d)$$

Where

- $\rho_b$  = dry bulk mass density of the soil, gm/cc
- $\theta$  = volumetric moisture content of the soil, dimensionless
- $K_d$  = distribution coefficient for the solute with the soil, ml/g

A reactive solute will travel at a slower rate (retardation) than the ground water due to adsorption. Laboratory analysis is optimized by using undisturbed soil samples and can be further refined by using actual field groundwater flow rates.



### Sample Requirements

- Soil: as a minimum, Extractables: 12 - 2 inch diameter x 6 inch long sleeves; Volatiles: 4 - 2 inch diameter x 6 inch long sleeves, of representative material from each location.
- Site Specific Separate Phase Contaminant: 5 liters with no preservative

### TAT

Dependant on number of samples / concentrations tested. 4-6 weeks can be used for planning.

### Cost

Approximately \$2500 - \$4500+ per sample. Cost will vary due to contaminant, soil type and site specific requirements.

### Client input required for firm cost and TAT

1. Contaminant or compound type.
2. Soil properties.
3. MSDS for contaminant.

### Reference:

Fetter, C.W. 1994. *Applied Hydrogeology*: Macmillan College Publishing Co., NY, pp 461-470.  
 Freeze, R.A., Cherry, J.A. 1979. *Groundwater*: Prentice Hall, NJ, pp 402-408.