ESM 222 Fate and Transport of Pollutants in the Environment

Lab #6: Advection & Dispersion in Porous Media

Due: 05/23/08

Objective:

Understand the parameters that control advection and dispersion in a porous medium:

- Permeability
- Porosity
- Pressure (hydraulic gradient)
- Dispersivity

Methods:

We will work with two test columns, one packed with medium sand and one with coarse sand. These two media have significant differences in porosity and permeability, due to differences in packing. Your group will work with only one of the two columns.

You will first measure the height of the water column, from the top of the free water surface (top air-water interface) where we assume the pressure is atmospheric (P = 1 atm) to the bottom of the sand and the porous material holding the sand in place. Water will be continuously added at the top using a hose, to maintain a constant Δh.

- Determine the hydraulic gradient, Δh, in m H_2O, and convert to atm, to get an idea of the pressure you build up in an aquifer. (10.3 m H_2O = 1 atm)
- Measure the flow Q out, by collecting outflow in a container for a set amount of time (e.g. 3 minutes) and determine the volume with a graduated cylinder. Report Q in m^3/s.
- Using Darcy's law, estimate the hydraulic conductivity, K in m/s, as well as the permeability, k in m^2.
- Estimate the specific discharge, q, in m/s.
- Estimate the actual water velocity v_w using n, in m/s. The TA will provide you values of porosity for each sand.

You will then run a tracer experiment using a photoactive dye. You will add a pulse of dye at the top of the column, mix it rapidly and then allow the pulse to move through the column. Water is continuously added at the top using a hose, to maintain a constant Δh.

- Collect the first sample about 20 s before you expect the pulse to start to break through.
- Collect samples in special cuvettes every 5 s, once the dye is near the bottom of the column.
- You only need a few ml per vial, and the dye is non-toxic and has very low volatility, so no need to cap the samples. Keep track of the sample number and time.
- After the pulse of die has passed, take your samples to the spectrophotometer to determine the concentration of the dye.
- Plot the normalized concentration, C/C_o, as a function of time since you mixed the dye in.
- Determine the mean travel time of the dye, v_p, in m/s.
- Determine the variance of the concentration profile (assuming it is Gaussian, or a normal distribution), σ^2.
- Determine the dispersion coefficient, D, in m^2/s
- Determine the dispersivity of the medium, α, in m.

Report and Analysis:

- Report and compare the permeability and hydraulic conductivity of the two media
- Report the porosity, dispersion coefficient and dispersivity for the coarse medium
- Determine whether there was any time lag between water and dye by comparing v_w and v_p for the coarse medium. Report the retardation factor, R.

The following is the solution for a 1-D tracer:

$$C(x,t) = \frac{M_0}{\sqrt{4\pi D_x^{'} t}} \exp\left[-\frac{(x - v_x^{'} t)^2}{4D_x^{'} t}\right] \quad (1)$$

Compare this result to a normal distribution:

$$C(x,t) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(x - \mu)^2}{2\sigma^2}\right] \quad (2)$$

where σ is the standard deviation, σ^2 is the variance and μ is the mean of the data. By comparing the two equations, you can see that $\sigma^2 = 2tD_x^{'}$. Thus, $D_x^{'}$ can be calculated from

$$D_x^{'} = \frac{\sigma^2}{2t} \quad (3)$$

where t refers to the time of the maximum concentration (the middle of the peak).