SSC 107 - LABORATORY EXERCISE 10

Solute Transport

Introduction

Miscible displacement is the process of replacing the existing soil solution with a solution of differing solute concentration. The solutions are miscible, thus mixing occurs at the boundaries of the solutions due to molecular diffusion and convective dispersion. Convective dispersion is the result of microscopic velocity distributions within soil pores as well as differences in pore sizes through the profile. The mixing that occurs at the boundaries of the solutions becomes more pronounced as the solute moves deeper into a soil column or soil profile. Thus, a solute pulse of finite volume becomes more "spread out" and the peak height lower as the pulse moves through longer soil columns. This behavior is shown by Figure 1 from Corey, et al. (1963, SSSAJ).

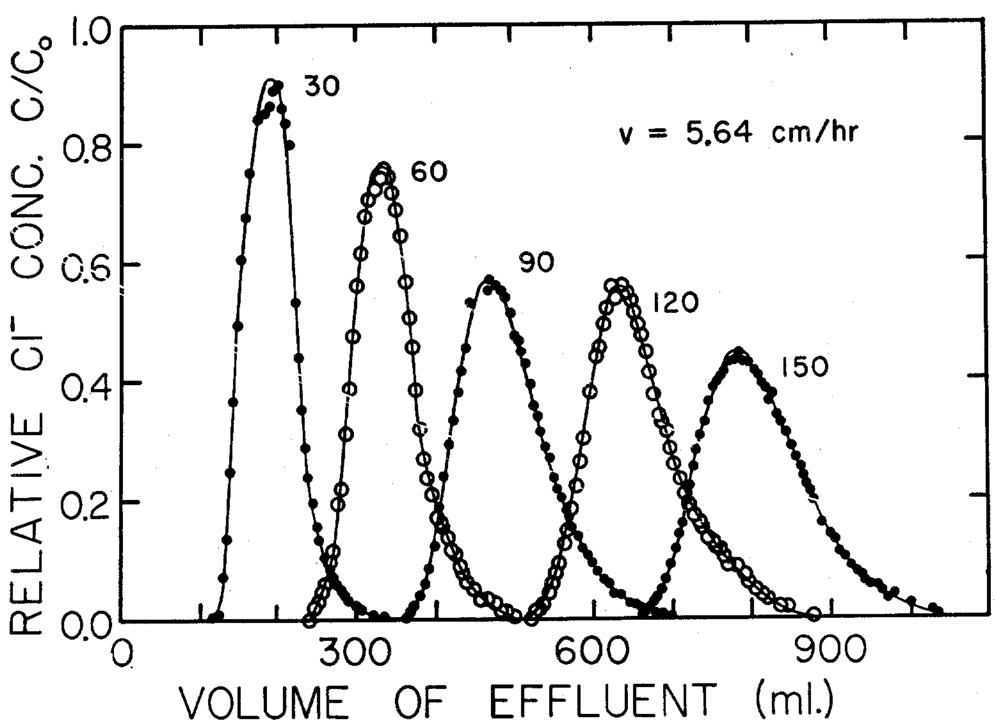

Figure 10-1: Relative chloride concentration distributions for 5 lengths of saturated sandstone for a displacement velocity of 5.64 cm/hr. The number by each curve represents the sandstone length in cm (Corey et al., 1963).

In addition to column length, the soil-water velocity, adsorption characteristics of the solute, and the dispersion coefficient of the solute will influence the shape and time that the solute elution will take.

Experimentally, elution or breakthrough curves are determined using apparatus such as shown in Figure 2.

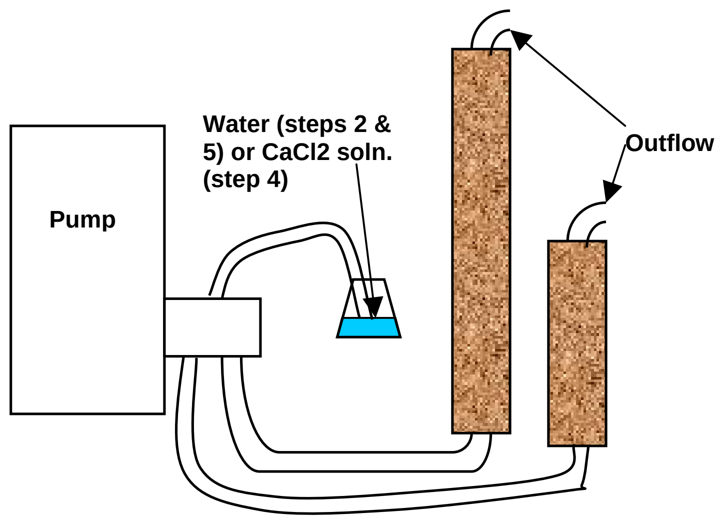

Figure 9-2: Schematic diagram of solute transport apparatus

The flow of a solution through a soil column is allowed to reach steady-state. The soil can be either saturated or unsaturated. At some time established as t = 0, a pulse or a step input of a displacing solution is applied to the entry end of the column by switching the flow from the initial solution to the displacing solution by switching from one burette to the other. The concentration in the effluent is then measured as a function of time or volume of the effluent.

Procedure

1. Pack a 20-cm and 40-cm column with fine sand. The bulk density should be approximately equal in both columns.

2. Connect one end of each column to the water pump system. The pump is set up to deliver the same amount of water to each column (i.e., the saturated flow rates in each column will the same).

3. While measuring the flow rate into a graduated cylinder, pump water through both columns until the flow rates in both columns become constant. The flow rate into the graduated cylinder needs to be measured only 3-4 times during this process. Calculate the volume of effluent that would pass out of the column during a 1 minute interval.

4. Apply a 15 ml pulse of 0.05 M $CaCl_2$ solution into each column.

5. After the pulse of 0.05 M $CaCl_2$ has entered the columns, continue pumping water through the columns. Collect effluent samples at 2 minute intervals into test tubes. Measure the electrical conductivity (EC) of each sample with the EC meter.

6. Collect effluent samples until the EC drops to its initial value.

7. Plot EC/EC_0 versus volume of effluent. EC/EC_0 is the conductivity of the sample divided by the conductivity of the influent solution. Plot the data from both columns on the same graph. The write-up should include a discussion of the similarities and/or differences in the graphs for each column. If they are different, why are they so?

Questions

1. What is the purpose of having the same flow rate in each columns?

2. In what ways would the results of this experiment be different if the columns were packed with clay instead of sand?

Lab Report Point Distribution

Abstract: 0.75
Materials and Methods: 0.5
Presentation of Results: 2.25
Discussion: 4.25
Conclusion: 1.5
Overall Composition: 0.75
Question 1: 0.25
Question 2: 0.75
Total: 10