Does Flow Direction Affect Solute Dispersion Across an Interface?

Josh Miner, Dr. Brian Wood

School of Chemical, Biological and Environmental Engineering, Oregon State University, Corvallis, Oregon 97331

1. Introduction:

The purpose of this research is to investigate how solute transport is affected by flow direction at an interface between two dissimilar homogenous media. Previous investigators have observed a dependence of the shape of the breakthrough curve on the direction of flow (fine-to-coarse versus coarse-to-fine). This is a somewhat unexpected result, that, until recently, has not been well understood in terms of basic transport theory.

Analytical solutions to this problem have been created by OSU researchers (E. Waymire, E. Thomman, and B.D. Wood)[Appuhamillage et al, 2010]. Previously reported experimental results [Berkowitz et al, 2009] were suggestive of this phenomena, but not sufficiently well controlled to be incontrovertible. The primary goal of this work is to develop high-quality data sets to provide solid physical evidence for the phenomenon, and to compare theory with the experimental results. This work has far reaching applications to microbial and abiotic colloid transport in the subsurface environment.

3. Current Results

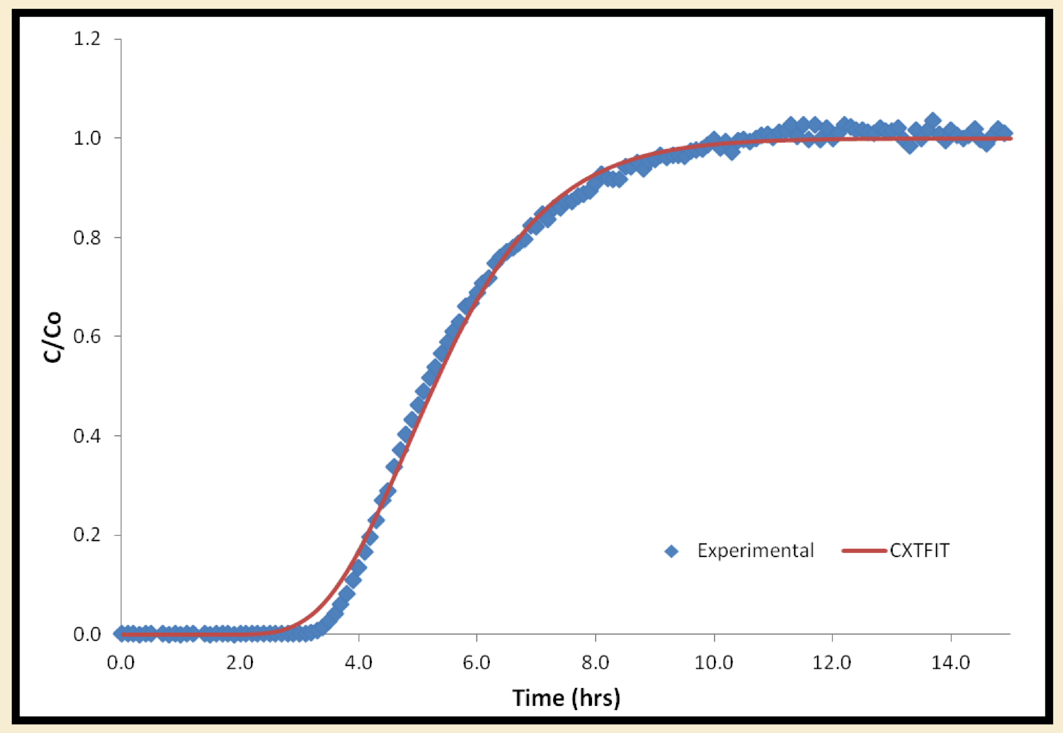

Figure 3: The breakthrough curve for the 6mm spheres shows a large dispersion of tracer.

Table 1: The results of inverse fitting concentration data with CXTFIT2 are encouraging. Dispersivity values are approximately 2-3 bead diameters as would be expected.

Media	V (cm/hr)	D (cm^2/hr)	α (cm)
Fine	4.42	0.86	0.19
Coarse	5.47	6.92	1.26

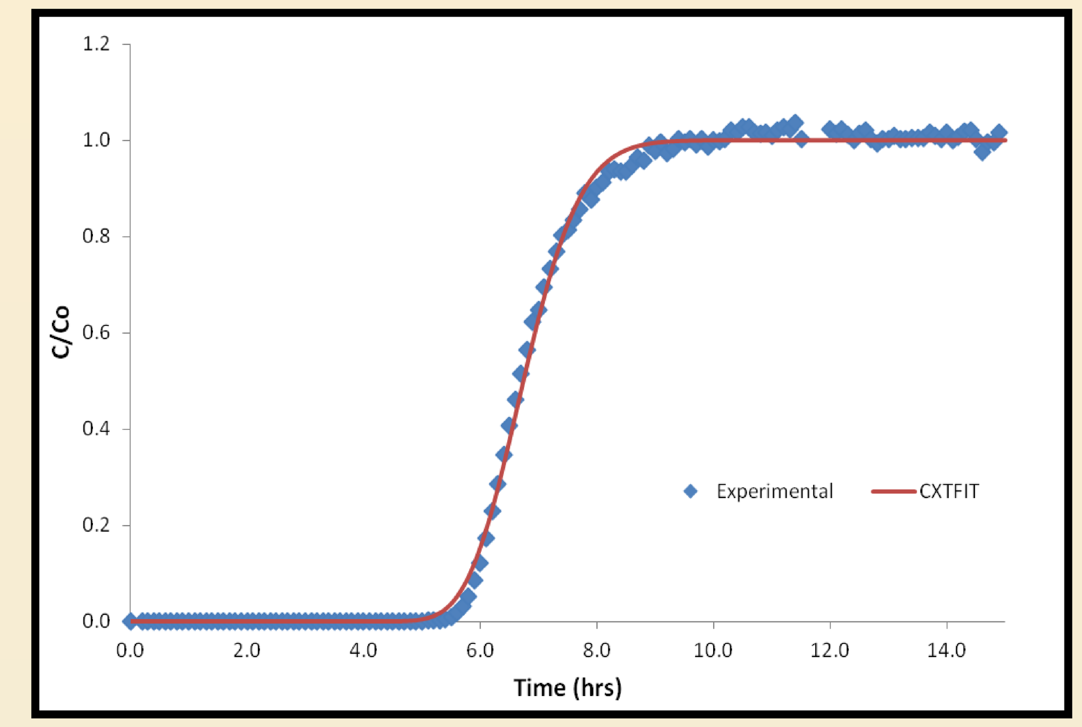

Figure 4: The breakthrough curve for the 0.6mm spheres shows the low amount of dispersion inherent in a bed of such small beads.

2. Methods

The experimental apparatus consists of two 30cm columns fitted together end-to-end. The porous material in one column is fine (0.6 mm) and in the other column (6 mm). A *breakthrough curve* (concentration versus time measured at the column effluent) is the measureable phenomenon; it is observed by recording the signal response of a tracer in the column effluent. Previous work has suggested that flow direction (fine-to-coarse versus coarse-to-fine) will influence the breakthrough curve, creating a different response curve for the two cases.

In this project, concentration monitoring is accomplished by using a fluorescent dye and a fluorescence spectrophotometer. The system was set up as depicted in Fig 1. The system was initially free of any tracer. Then, at t = 0 min, tracer was pumped through the system at a flow rate of 1.64 mL/min using a dual-syringe continuous flow pump.

The tracer is a 1ppm solution of Sulforhodamine B, and the tracer signal in the effluent was measured continuously with a flow cell installed directly in the spectrophotometer. Special precautions were taken to remove air bubbles that could become trapped in the flow cell, causing a decrease in signal intensity and an increase in noise.

Values for the bed velocity, the dispersion coefficient, and the dispersivity were obtained by performing an inverse fit of the observed breakthrough curve data using the code CXTFIT2 [van Genuchten et al, 1999].

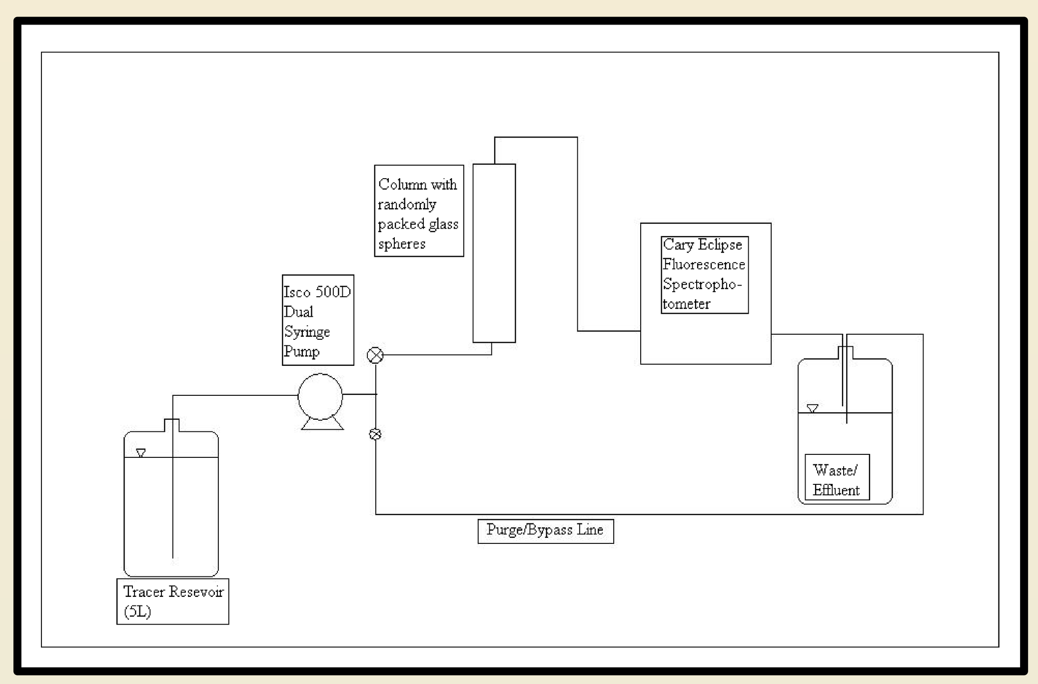

Figure 1: A schematic of the experimental system.

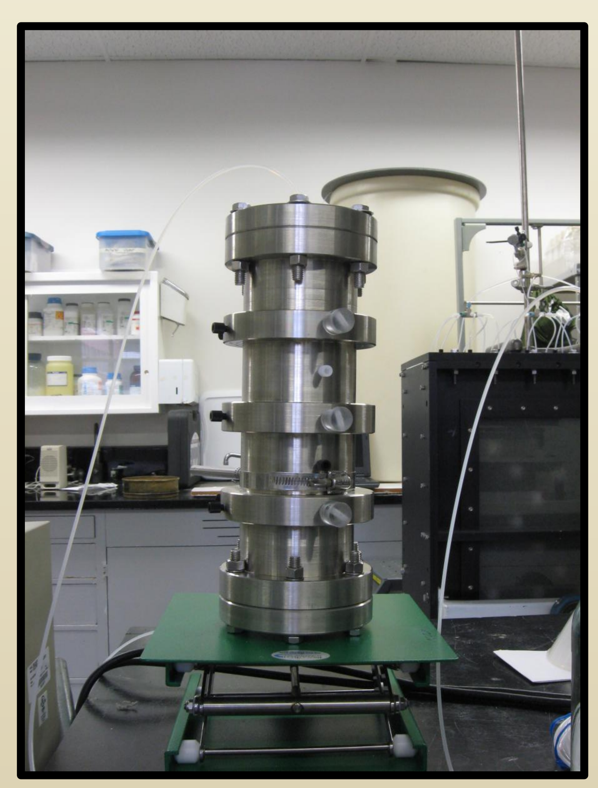

Figure 2: One of the 30cm columns.

4. Conclusions and Future Work:

The phenomenon that we want to observe is subtle, so great care is required in the experimental method to reduce error and produce useful results. Preliminary findings suggest that the two selected media will work well. The next step is to move on to the full scale column, with two regions, and investigate the affect of flow direction at various flow rates. This work is still in progress, and our long term plans are to conduct additional experiments using bacterial cells as the transported constituent. Other future work will include *in situ* measurement of the transported constituent using fiber optic probes inserted at intervals in the column and connected to the fluorometer.

References:

1. Appuhamillage, T.A., V. Bokil, E. Thomann, E.Waymire (2010), Solute Transport Across an Interface: A Fickian Theory for Skewness in Breakthrough Curves, *Water Resources Resarch, ??,XXX*, DOI:10.1029/
2. Berkowitz, B., A. Cortis, I. Dror, and H. Scher (2009), Laboratory experiments on dispersive transport across interfaces: The role of flow direction, *Water Resources Research, 45, W02201, doi:10.1029/2008WR007342*
3. van Genuchten M., F. Leij, N. Toride (1999), The CXTFIT Code for Estimating Transport Parameters from Laboratory or Field Tracer Experiments, Version 2.1, Research Report No. 137, U.S. Salinity Laboratory, USDA, ARS, Riverside, CA.

Acknowledgements:

I thank Vishal Patil for his advice and assistance with this project, and the Subsurface Biosphere Initiative (Dr. Lewis Semprini) for providing the funding to do this research.

OSU Oregon State University

Subsurface Biosphere Initiative
Research and education focused on life below Earth's surface.