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A Review of Field-Scale Physical Solute Transport Processes in Saturated and Unsaturated Porous Media

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ABSTRACT

The development of accurate mathematical models to predict field-scale solute transport in the saturated and unsaturated zones is hampered by the lack of reliable data on field-scale transport parameters. A critical review of the available literature on studies conducted at 55 saturated zone and 28 unsaturated zone sites produced 99 and 8 longitudinal dispersivity values, respectively.

In the saturated zone, the scale of observation for all the data ranged from 0.75 m to 100 km with longitudinal dispersivities from 0.01 to 5500 m. However, only five sites produced highly reliable dispersivity data, based on an evaluation of the test configuration, the tracer monitoring, and the data analysis method for each site. The largest scale of high reliability dispersivities was only 115 m. The high reliability data subset indicates that the dispersivity initially increases with the scale of observation. But it is not clear whether the dispersivity increases indefinitely with scale or reaches an asymptotic value as is assumed in classical modelling and predicted by recent stochastic theories.

In the unsaturated zone the dispersivity ranged from 1 mm to 0.7 m and appeared to increase with the scale of observation from 1 m to 20 m; however, most experiments were at scales of about 2 m. The transport process is dominated by the lateral movement of solutes in dry, high tension soils whereas in nearly saturated soils the solutes and water can move rapidly downward through the the macrostructures.

There is a clear need to conduct controlled large-scale field experiments in both the saturated and unsaturated zones to obtain reliable dispersivities at increasing scales and to identify the controlling transport mechanisms.

CONTENTS

SUMMARY

The first part of the report examines solute transport processes in the saturated zone. The principal objectives of that section are to (1) review all available literature where values of field-scale dispersivity were reported; (2) perform detailed analyses of data from selected sites to illustrate alternative methods and data interpretation; (3) evaluate the data collected and make a judgement regarding its reliability; and (4) draw conclusions and provide recommendations relating to the design of field experiments.

From the literature search, 55 sites were found where a total of 99 values of longitudinal dispersivity were reported. These ranged from 0.01 m to more than 5500 m at scales of 0.75 m to 100 km. From a first look at the data, without consideration of the quality of the data, it would appear that dispersivity increases indefinitely with scale. It should be noted that there is a paucity of data in the literature on horizontal and vertical transverse dispersion. Only 22 and seven values of horizontal and vertical dispersivity, respectively, were reported. This is an important data gap in light of the fact that contaminant plumes are three-dimensional in nature.

In addition to dispersivity values, a number of parameters for each site were tabulated to determine whether there was a relationship between these parameters and dispersivity. Upon examination of the data, there do not appear to be any such relationships.

Two sites having extensive, good quality data were re-evaluated to illustrate alternative methodologies and interpretations. Data from the Borden site in Canada were used to illustrate the method of second moment analysis to estimate three-dimensional dispersion characteristics and to demonstrate dependence of the dispersivities on displacement distance. Data from the Bonnaud site in France were used to demonstate the application of stochastic theories for predicting macrodispersion in aquifers.

The data collected from the general review were critically evaluated to determine how well field-scale dispersivity was actually measured by the tests conducted.