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ABSTRACT TITLE: Geoelectrical Measurement of Multi-scale Mass Transfer Parameters

ABSTRACT: Evidence of dual-domain mass transfer (DDMT) includes long "tailing" behavior and concentration rebound during aquifer remediation. The lack of experimental methods to verify and measure mass transfer in-situ independently of tracer breakthrough results in significant uncertainties in estimates of controlling parameters. Our objectives are to develop geophysical strategies to measure mass-transfer parameters over a range of spatial scales, and to demonstrate these strategies to produce estimates of mass-transfer parameters for Hanford 300 Area materials. Here, we assess the utility of time-lapse electrical resistivity (ER) and complex resistivity (CR) to improve the basic and site-specific understanding of mass transfer. During our final year of funding, we focused on (1) ER and CR laboratory experiments; (2) comparison of ER and CR results to nuclear magnetic resonance (NMR) measurements of mobile and immobile porosity; and (3) pore-network modeling of the electrical signature of mass transfer. Column ER/tracer-test experiments were performed using two samples of the porous zeolite clinoptilolite, which is a known dual porosity medium. We used glass beads and well sorted sand as two reference samples in which tailing behavior is not evident. Parametric sweeps using the model STAMMT-L identified best-fit DDMT parameters for the range of samples studied.

A comparison of solute transport behavior for the two zeolites revealed contrasting DDMT characteristics. For example, longer solute residence times were evident for the finer grained zeolite, for which NMR spectra indicate greater immobile porosity. The utility of CR methods for determining DDMT characteristics is ongoing. Debye decomposition analysis of CR spectra revealed a dominant relaxation time that appears to be controlled by grain size, which may have limited value for assessing mass-transfer properties. There is, however, an observed increase in polarization associated with short relaxation times with increasing immobile porosity as measured by NMR. From this we infer that the CR spectra are sensitive, in these examples, to the intra-grain porosity and hence physical characteristics that influence mass transfer.

Pore-network models qualitatively reproduce the hysteresis observed in time-lapse ER but indicate that the bicontinuum Archie model used previously systematically over predicts the contribution of immobile porosity to bulk conductivity. Alternative petrophysical models have been developed to account for different internal connectivity for mobile and immobile domains, providing a superior fit to the pore-network simulations of the bulk-fluid conductivity relation.

Infiltration and tracer experiments were conducted to assess the DDMT properties of the vadose zone in the Hanford Integrated Field Research Challenge well field in July of 2012. Data exhibit DDMT behavior. Analysis involves calibration of models to the breakthrough data and comparison to the electrical measurements. Publications on results from zeolites and pore-network modeling are in preparation. To date, three papers from this project have been published, and a fourth is undergoing revision. Ongoing work focuses on (1) analysis of field-experimental data, (2) development of the CR-NMR spectra analysis combining additional measured physical properties (e.g. surface area) (3) additional pore-scale modeling of the geoelectrical signature of DDMT.