Geoelectrical Measurement of Multi-scale Mass Transfer Parameters

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Evidence of mass transfer at contaminated sites includes long "tailing" behavior and concentration rebound during remediation of groundwater. The lack of experimental methods to verify and measure mass transfer in-situ or 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 the second 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 samples of the porous zeolite clinoptilolite, which has well defined mass-transfer properties. Parametric sweeps identified best-fit transport parameters. The estimated mobile and immobile porosities are consistent with measurements using NMR. Analysis of CR spectra measured on sieved fractions of the same zeolite, using a Debye decomposition approach, reveals different relaxation-time distributions. Time-lapse measurements of CR in columns under tracer loading show a time-/frequency-dependent response to reactive transport. These results also show a disconnection between real and imaginary components of the CR spectra relating to surface chemistry of the immobile and mobile domain. This method is currently being applied to a sieved-fraction composite sample from the Hanford 300 Area. Initial analysis of relaxation-time distributions indicate correlation with transport parameters and NMR relaxation-time results. Hanford materials have been obtained and are under study. We also are capitalizing on CR analyses performed for the IFRC on Hanford cores by collaborators at Rutgers U. 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. A multiphase Archie model, which allows for different internal connectivity (i.e., formation factor) for mobile and immobile domains, provides a superior fit to the simulated bulk-fluid conductivity relation

Fieldwork to install ER/temperature/sampling probes took place in March 2012 in preparation for summer field experiments. Infiltration and tracer experiments will assess the mass-transfer properties of the vadose zone and 'smear zone.' Additional ER and CR work on Hanford materials is ongoing, and publications on results from zeolites and pore network modeling are in preparation. To date, two papers acknowledging this project have been published. In the final year of our grant, we will focus on integrating insights from our pore-, laboratory-, and field-scale investigations.