

Electrical Evidence for Solute Mass Transfer at the Lab-scale

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Previous field-scale experimental data and numerical modeling suggest that the dual-domain mass transfer (DDMT) of electrolytic tracers has an observable geoelectrical signature. Here, we present controlled laboratory experiments confirming the electrical signature of DDMT and demonstrate the use of time-lapse electrical measurements to estimate the parameters controlling the DDMT, i.e., the mobile and immobile porosity and rate at which solute exchanges between mobile and immobile domains. We conducted column tracer tests on unconsolidated quartz sand and a material with a high secondary, internal porosity: the zeolite clinoptilolite. During NaCl tracer tests, we collect nearly co-located bulk direct-current electrical conductivity (σ_b) and fluid conductivity (σ_f) measurements. Our results for the zeolites show (1) extensive tailing behavior and (2) a hysteretic relation between σ_f and σ_b , thus providing evidence for a mobile-immobile framework not observed within the quartz sand. To identify the best-fit parameters and evaluate parameter sensitivity, we perform over 2700 simulations of σ_f , varying the immobile and mobile domain and mass transfer rate. To emphasize the fit to late-time tailing behavior, transport parameters are estimated by minimizing the Box-Cox power transformed root-mean-square error between the observed and simulated σ_f . Nuclear magnetic resonance (NMR) measurements provide an independent quantification of the volumes of the mobile and immobile domains. The best-fit parameters match our NMR measurements of the immobile and mobile domain porosities and provide the first direct electrical evidence DDMT and solute exchange at the lab scale. Our results underscore the potential of using electrical measurements for determining the controls on solute transport.

