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Experimental and Numerical Analysis of Transport in Saturated Heterogeneous Media

The conventional advection-dispersion equation cannot adequately describe all processes driving solute transport in heterogeneous systems. This dissertation focuses on the individual influences of both chemical (Chapter 2) and physical processes (Chapters 3 and 4) which affect solute transport. In Chapter 2 we analyzed uranium transport in natural sediment using the chemical multirate mass transfer model available within the STAMMT-L software. This model was used due to many uncertainties of the overall mass transfer influences, which were generalized into a distribution of first-order rate coefficients. Results indicated that the multirate model was adequate for the available experimental data, but the results were not definitive due to incomplete mass recovery information. A second experimental system was constructed in order to provide a well-characterized system for analysis. It consisted of 203 low conductivity (Kim = 0.011 cm/min) spherical inclusions within a high conductivity (Km = 4.66 cm/min) matrix material, creating a highly heterogeneous binary system with a conductivity ratio of 1/424. Three flow rates were used to provide complete mass recovery curves. Results were initially analyzed using a multirate spherical diffusion model available within the STAMMT-L software (Chapter 3). This worked well for the fast and medium flow rate experiments, while its representation of the slow flow rate experiment proved inadequate. An analysis of the time scales for mass transport indicated that the diffusive time through the inclusions was competing with advection through the matrix as the dominant mass transport mechanism. Subsequent modeling was performed by direct numerical simulation using the commercially available STAR-CCM+ software (Chapter 4). Results showed inconsistencies with its ability to adequately describe the system when compared with the multirate model results. This dissertation provides insight into the importance of gathering complete mass recovery data, obtaining detailed measurements to describe the system, as well as analysis of results from multirate solute transport processes in order to obtain an improved understanding of their influences on overall mass transport behavior.

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