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A New Paradigm for Pathogen Transport and Deposition in Porous Media: The Role of Pore Structure and Colloid-Colloid Interactions

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Abstract Text:

Despite decades of research, we are unable to accurately predict the retention of pathogens and other colloids in granular aquifer media under environmental conditions, where repulsion exists between colloids and surfaces. The failure of existing colloid filtration theory (CFT) is not simply due to inaccuracy of pore domain characterization, since CFT works well in the absence of colloid-collector repulsion, and fails completely when such repulsion is present. Rather, the failure of CFT stems from failure to incorporate the correct mechanisms of retention when repulsion exists. In the presence of an energy barrier, recent observations implicate colloid retention in grain to grain contacts, pore throats, and in secondary energy minima. Mechanistic simulations in unit cells containing grain to grain contacts corroborate these mechanisms of colloid retention. The resulting concept for colloid retention in the presence of an energy barrier involves translation of colloids across the collector surfaces (outboard of the energy barrier) until they become retained by these mechanisms. The near-surface accumulation of colloids enhances the likelihood of colloid-colloid interaction, which would be expected to reduce the number of colloids retained in zones of low fluid drag and which would be expected to enhance colloid aggregation in grain to grain contact zones.

This presentation summarizes recently funded USDA-CSREES research (2006-02541) to develop models for pathogen and colloid transport (and retention). Model development includes incorporation of colloid-colloid interaction into mechanistic particle trajectory simulations in representative unit cells for porous media. The simulated collector efficiencies (probability of colloid retention) are being compared to experimental observations across a spectrum of aquatic conditions and scales. Experimental approaches include column transport experiments, direct-observation impinging jet (and other micromodel) transport experiments (e.g. TIRF), measurement of pathogen-surface and pathogen-pathogen interaction forces by atomic force microscopy (AFM), and determination of pathogen-surface and pathogen-pathogen interaction forces from extended DLVO theory.

Impact Statement:

The resulting mechanistically based models will improve our ability to assess and predict the transport and fate of pathogens in subsurface environments. This information will also facilitate the development of improved animal waste management practices to minimize pathogen contamination of water resources, and thereby help safeguard drinking water supplies.