Transport and Retention of Motile Microbes in Pore Networks: Progress and Plans

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This project seeks to understand the motion and retention dynamics of motile microbes at the micro- and pore-scale and utilize upscaling techniques to study impacts of microbial motility on metal bioremediation simulations at the field-sale. A series of experiments with motile bacteria, using microfluidic devices and advance imaging techniques, were conducted (and are planned) to quantify the fundamental character of bacterial motion in porous media during active swimming. The experiments form the basis for development and testing of new models of microbial transport and retention. Trajectories of individual cells for several metal reducing species were analyzed to provide information on the length of runs, and time needed to complete a run. These motion statistics were used to construct a continuous time random walk model and its performance in reproducing real breakthrough plots were compared against traditional modeling approaches based on the advection diffusion equation. We have further employed random walk particle-tracking (RWPT) approaches to elucidate the impact of porous media confinement and cell-cell interactions on the overall bacterial transport. We validated our RWPT model against single-cell resolution data from 3D porous media which showed that the model can efficiently simulate the spreading dynamics of motile bacteria in confined geometries. More recently, we have extended our micromodel experiments to study spatial organization of biofilms in pore networks and evaluate the impact of biofilm-induced flow heterogeneities on conservative transport. Biofilm images were processed to represent them as a synthetic porous structure in numerical models. With biofilms present, we observed enhanced solute spreading in breakthrough curves that exhibit extreme anomalous slopes at intermediate times and very marked late arrival due to solute retention. We are currently integrating micro-scale models with pore-scale simulations and using it to generalize and upscale microbial transport to a broader range of pore geometries and flow conditions. In the coming months, the results of pore-scale simulations will be used to parameterize effective transport and retention properties for field-scale models of microbial transport that can be incorporated into existing simulators of metal bioremediation.