Flow Hydrodynamics and Transport Characteristics in Presence of Permeable Biofilms

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Project Abstract:

Biofilm images of Paenibacillus 300A strain, obtained from two-dimensional micromodel experiments, formed the basis for studying spatial organization of biofilms in pore networks and evaluation of their impact on flow and conservative solute transport characteristics. The micromodels were designed with hexagonal packing of equal diameter grains to simulate a pore network environment with simple parabolic flow profiles. Biofilm images were processed to represent them as synthetic porous structures with locally varying physical properties. The inclusion of these microstructures causes higher degree of spatial correlation in the numerical model, and produces local velocities orders of magnitude slower than those found in the main channels (away from the biofilms) of the micromodel. This flow heterogeneity leads to enhanced solute spreading in the breakthrough curves that exhibit extreme anomalous slopes at intermediate times and very marked late solute arrival times due to retention imparted by low velocity and stagnation zones. The efficiency of solute retention by the biofilms (i.e., trapping of solute particles within biofilm microstructures) is manifested in the long tailing of the breakthrough curves. The study shows that solute retention by biofilms exerts a strong control on conservative transport at the pore-scale, a role that has not received enough attention in the past. The integrated experimental and modeling approach is expected to serve as building blocks in understanding impact of biofilms for a broader range of pore geometries and flow conditions with implications for applications such as metal bioremediation.