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Intermittent shifting of preferential flow paths in bioclogged porous media enhances mixing-driven reactions

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Microorganisms can establish organized biofilms in many natural and engineered porous media systems with significant advantages to applications such as biofilm barriers to groundwater pollution. The formation of thick biofilms can change the pore structure and consequently alter the hydrodynamics and reactive transport in porous media. Yet, the impact of preferential flow path formation and spatiotemporal rearrangement on overall system reactivity in bioclogged systems remains poorly understood. A two-dimensional pore-scale numerical model was developed to examine the effect of mixing and reaction efficiency upon biofilm development, biomass growth scheme, and preferential flow path stability. Simulations of water flow and solute transport in the porous medium were coupled to a biomass growth and attachment model scheme for a period of 400 hours. Four biomass growth models were tested, including i) no decay, ii) kinetic decay, iii) degradation, and iv) mechanical detachment. Our results indicate that i) permeability reduction and variations in the biomass fraction reached a similar and quasi-constant value after 100 hours for all growth models, ii) the shifting location of preferential flow paths only occurred when biomass growth was overcome by the combination of shear forces with biomass decay and/or degradation, iii) flow stagnation zones enhance the formation of strong concentration gradients, and iv) the preservation of high overall reactivity within the system requires intermittent shifting in the location of preferential flow paths.

Participation

In-Person

References

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Primary author: MORALES, Veronica (University of California, Davis)

Co-author: ZHOU, Jiahui (University of California, Davis)

Presenter: MORALES, Veronica (University of California, Davis)

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