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Chemotaxis promoted bacterial transport toward residual NAPL in a dual-permeability microfluidic device

Thursday, 2 June 2022 15:15 (1h 10m)

Nonaqueous phase liquid (NAPL) contaminants which persist in subsurface environments due to low solubility and flow heterogeneity may be more accessible to chemotactic bacteria in bioremediation contexts. Chemotactic bacteria bias their swimming motion upon sensing chemical gradients, such as performing longer runs toward sources of chemoattractants (e.g., naphthalene), which increases the contact of microbes and NAPLs. This work aimed to investigate the transport of chemotactic bacteria in a dual-permeability microfluidic device with chemoattractant-containing NAPL under flow conditions, mimicking NAPL contaminated aquifers. Microscopic imaging of bacteria in the pore space revealed accumulation of chemotactic bacteria near NAPL surfaces at the junction of high and low permeability areas; however, no chemotaxis was observed near NAPL in flow through pathways. Weak convection and steeper chemoattractant gradients in the junction regions strongly regulated the transport of chemotactic bacteria, according to our simulations, which fully captured the pore geometry. We also applied continuum-level models of bacterial transport where dispersion was included in diffusion term to account for the effect of flow heterogeneity. Chemotactic bacterial transport in porous media often requires adjustments of chemotactic velocity to a certain extent to match experimental data. However, our simulation required no modification in chemotaxis convection term, rather a 50% increase in the dispersion of chemotactic bacteria, which is consistent with conclusions in de Anna et al. (2020) that chemotaxis can modulate bacterial dispersion in porous media. The experiment and simulations provide insight into the interplay between chemotactic bacteria and pore-scale chemical gradients, and its impact on macroscale transport in subsurface environments.
Studies in liquid media showed chemotaxis toward NAPL was undermined at higher flow velocities. However, in porous media, chemotactic bacteria can benefit from stronger convection by being brought to closer contact with residual NAPL in the junction regions. In our experiments of bacterial transport under varying pore velocities, maximum accumulations of chemotactic bacteria at the junction were achieved at fluid velocities much higher than those in Wang et al. (2012). To understand the effect of pore confinement on bacterial transport, we proposed two time scales related to convection and chemotaxis, respectively, and applied machine learning techniques to investigate the correlation between bacterial accumulation and physical conditions such as pore velocity, chemical distribution, and pore dimension.

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References

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Time Block Preference

Time Block B (14:00-17:00 CET)

Participation

Online

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