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Bacterial Accumulation near Residual Organic Pollutants in Micropockets of Porous Media Depends on Chemotaxis and Pore Water Velocity

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Groundwater contamination caused by nonaqueous phase liquids (NAPLs) is a significant environmental concern as NAPLs are ubiquitous and persistent pollutants, remaining recalcitrant to bioremediation due to their low solubility and limited bioavailability. Chemotaxis, the biased migration of motile bacteria toward chemical gradients, may facilitate remediation of NAPLs by transporting pollutant-degrading bacteria to residual contaminant sources trapped within the soil matrix. Greater accumulation of chemotactic bacteria was observed in Gao and coworkers'study near NAPL contaminants at the juncture between different permeability regions in a heterogeneous micromodel [1]. Bacterial distributions in the pore space were influenced by chemical gradients and fluid flow, whose combined effect on bacterial transport is not well characterized in porous media. In this work, we aimed to investigate the transport mechanism of chemotactic bacteria from moving pore water into stagnant micropockets formed by oil-phase contaminant ganglia.
Chemotactic bacteria (*Pseudomonas putida* G7) were introduced at varying fluid flow rates (0.2-56 m/d) into a dual-permeability microfluidic device contaminated by NAPL. Bacterial suspension flowed preferentially through the highly permeable area while the low-permeability regions retained NAPL, which served as contaminant sources. Bacteria showed accumulation in micropockets near junctures of high- and low-permeability zones due to chemotaxis. However, accumulation in micropockets was initially increased and then decreased as pore fluid velocity increased in each trial. Convection in porous media did not simply override chemotaxis as previously observed in bulk liquid [2]; instead, higher pore velocity brought bacteria closer to NAPL sources than diffusion alone and triggered stronger chemotactic response by creating steeper chemical gradients. The optimal pore velocity, in terms of maximum bacterial accumulation, depended on the time scale of exposure to chemicals. Bacterial exposure time to chemical gradients was estimated to be $\tau e=L/Vp$, where L was characterize pore dimension and Vp fluid velocity. When exposure time exceeded response time (~ 2 s in Pseudomonas putida [3]), bacteria in bulk flow did not have sufficient time to bias their swimming directions in response to the presence of NAPL contaminants. Our results indicated that in heterogeneous porous media chemotaxis could be enhanced by fluid flow rather than merely being suppressed and chemotactic bacteria would lose their advantage when their exposure time to chemicals was below the threshold of response time. Results from this study suggest that accumulation of NAPL-degrading bacteria in porous media micropockets will facilitate biofilm formation and enhance bioremediation. The dimensionless group of parameters comparing response time to exposure time will aid practitioners in determining an appropriate pore water velocity to use in delivering chemotactic bacteria for in situ bioremediation.

Participation

In-Person

References

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