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The Chemical/Biological Remediation of Non-Aqueous Phase Liquids in Heterogeneous Porous Microfluidic Devices

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Over the years, crude oil spills have occurred frequently, resulting in large amounts of toxic organic contaminants seeping down into the onshore soil-groundwater system. These non-aqueous phase liquids (NAPLs) can easily attach to soil particle surfaces and are difficult to eliminate, harming the environment continuously. Besides, the heterogeneity of soil makes the distribution of NAPL contaminants more complex, and it is difficult for conventional restoration agents to make sufficient contact with the NAPL in the low permeable zone, resulting in poor remediation. Therefore, proposing efficient and eco-friendly remediation methods of NAPL contaminated layers in heterogeneous soil-groundwater system is increasingly urgent.
In this study, a new eco-friendly chemical reagent and chemotactic bacteria were adopted to try to solve the problem above. The chemical reagent is dihydrolevoglucosenone, commercially known as Cyrene. Cyrene is a highlighted renewable and highly biodegradable cellulose-derived solvent, an attractive substitute to widely used toxic dipolar aprotic solvents. When added to water, Cyrene behaves as a hydrotrope, increasing the aqueous solubility of hydrophobic solutes to a great extent. Chemotactic bacteria have perceptions of contaminant concentration gradients in water and can make response to it by preferentially swimming towards regions of higher contaminant concentration. We designed a series of microfluidic devices with dual-permeability to simulate the heterogeneous soil contaminated with NAPL, and studied the efficiency of Cyrene (compared with the conventional surfactant Tween 80) and chemotactic bacteria to clear the NAPL contamination under different groundwater flow rates.
Our experimental results showed that though distilled water could displace a portion of the oil in the high permeable region of the microfluidic device, no explicit decrease of oil in the low permeable region was observed under different water flow rates. Better displacement effects were obtained in surfactant flooding. We found that the surfactant flooding with Tween 80 could produce fingering phenomenon in the low permeable area, and the fingering extent was related to water velocity and surfactant concentration. The flooding with Cyrene showed a better remediation effect compared with water and Tween 80 at the same flow rate, and the higher the concentration of Cyrene, the less the NAPL residuals were in the chip. We also injected chemotactic bacteria suspension into the chip after the three types of fluids displacement above, and found that considerable bacteria tended to accumulate at the interface between the high and low permeable regions after water flooding; and more chemotactic bacteria were found in the low permeable region after the surfactant and Cyrene flooding. Our findings provide a novel idea to use chemotactic bacteria and green chemicals to improve the remediation of NAPL contamination in heterogeneous soil structures.

Time Block Preference

Time Block A (09:00-12:00 CET)

References

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