Emulsified Oil Distribution in Heterogeneous Aquifers: Designing Efficient Injection Systems

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Emulsified edible oils have been injected at hundreds of sites throughout the world to stimulate anaerobic biodegradation of chlorinated solvents and other anaerobically biodegradable contaminants. However to be effective, the oil droplets must be brought into close contact with the contaminant to be treated. This can be challenging in heterogeneous aquifers where large spatial variations in hydraulic conductivity make it difficult to uniformly distribute the oil droplets.

In the emulsified oil process, a specified volume of emulsified oil and water are injected into the aquifer through an array of temporary or permanent wells. The oil droplets are transported through the aquifer by the ambient or induced groundwater flow until they attach to sediment surfaces. Once attached, the oil is gradually fermented to hydrogen and low molecular weight fatty acids that drive anaerobic biodegradation of chlorinated solvents and other anaerobically biodegradable contaminants. In general, there are only a limited number of approaches that can be used to improve the oil distribution: (a) injecting more oil; (b) injecting more water; (c) using more closely spaced wells; and (d) varying the location and/or timing of the injection. All of these approaches can potentially be effective. However, there is no available information on the effect of these different approaches on the injection system performance.

The numerical models MODFLOW and RT3D were used to simulate emulsion transport and distribution in spatially heterogeneous aquifers using a rate limited Langmuir sorption approach. The hydraulic conductivity field was generated using the Turning Bands Method with three different levels of heterogeneity: low, medium and high. Injection approaches included simultaneous and sequential injection of wells arranged in grids and barriers. Injection performance was evaluated by calculating volume-weighted and flow-weighted contact efficiencies. Performance curves were then generated illustrating the effect different design variables on contact efficiency.

A spreadsheet based tool has been developed to assist designers in planning efficient, lower cost injection systems. Information on aquifer parameters and costs for labor, material and well installation are entered first. Results from the MODFLOW/RT3D model simulations are incorporated as a series of performance curves illustrating the effect of different design variables (e.g. amount of oil, amount of water, injection well spacing, injection pattern) on oil distribution. The designer can then easily evaluate the effect of different injection approaches on oil distribution, initial capital cost and 30-yr life cycle costs.