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Mobility-Control Methods to Improve the Delivery and Distribution of Bioremediation Amendments in Heterogeneous Aquifers

Jeffrey A.K. Silva, PhD (jsilva@gsisg.com) (GSI Pacific, Inc., Boulder, CO, USA)

Background/Objectives. Mobility-control methods have a long history of research and application in the petroleum industry in support of enhanced oil recovery. However, while these methods have also been shown to have significant promise in improving the subsurface delivery of injected environmental remediation fluids within heterogeneous geomedia, they have not yet been widely adopted for use in remediation practice, perhaps because of practitioner uncertainty of the practical benefits and limitations of the approach or an incomplete understanding of the ease at which these methods can be incorporated into an existing remedial design. Mobility control, for environmental remediation, can include the use of solution viscosifiers (e.g., water soluble polymers) or foams generated in-well and/or in-formation from solution, both of which reduce the mobility of the injected fluid within more permeable strata, creating a flow resistance that enhances the delivery of fluids to adjacent less permeable strata that would generally be bypassed as a result of preferential flow. The net result is an improved subsurface distribution of remedial fluids (i.e., improved sweep efficiency) and improved contact between the remediation agent and source of contamination. It is the objective of this presentation to clarify the mechanism of mobility control and present the results of recent research in which the practical benefits and limitations of these techniques are critically evaluated. Bioremediation-specific applications will be highlighted. For example, the use of mobility-control methods to improve the delivery and penetration fluids into lower permeability strata can also improve the longevity of treatment by creating an emplaced source of bioamendments and/or bionutrients that can slowly dissolve back into the main flow field.

Approach/Activities. With respect to viscosity-modification using water-soluble polymers, laboratory batch and 2-D tank experiments were performed to provide data to support numerical simulation (UTCHEM). The simulator was thereafter used to expand the test database to include flow and heterogeneity scenarios beyond what could be reasonably achieved in the laboratory. Experimental variables included solution viscosity, solution rheology, media permeability contrast (sands to silts), and the degree and order of geomedia layering. The results of a recent field-scale demonstration will also be presented.

Results/Lessons Learned. The degree to which viscosity-modification mitigates permeability structure and improves sweep efficiency increases with increased solution viscosity. However, solution viscosities need not be excessive to maximize sweep-efficiency improvement. For a heterogeneous aquifer consisting of sands to silts, a viscosity of 10 to 30 centipoise (i.e., in the range of olive oil to linseed oil) is all that is needed. Viscosifiers that provide a non-Newtonian shear-thinning rheology are useful to minimize injection pressures during treatment, and are recommended where the water table is shallow. However, a stable Newtonian viscosity is just as effective. When maximal permeability contrasts are less than 4, 100% sweep can be achieved in 1 pore volume. For permeability contrasts between 4 and 20, 100% sweep can be achieved in less than 2 pore volumes. When the permeability contrast is greater than 20, an alternative delivery strategy (e.g., fluid re-circulation or foam applications) should be considered. Foam applications are particularly useful to address more significant permeability contrasts (e.g., gravel thief zones), as strong foams can significantly reduce the mobility of injected remedial fluids within the more conductive strata.