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Optimization of Well Patterns in Fractured Media

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Recovery of non–aqueous phase liquids (NAPLs) from the subsurface is problematic, and a serious concern for the environmental community. Many treatment approaches are focused on in–situ approaches, either in–situ treatment or recovery of NAPLs, that rely on injecting remedial fluids into the subsurface. Consequently, an understanding of flow behavior within fractured media, and the ability to numerically model flow in fractured rock, is of special interest to environmental practitioners and the focus of this poster.

A transparent physical model was constructed with fractures of 3 aperture sizes (0.5, 0.2, and 0.1 mm) and used to demonstrate the vertical flow behavior in fractured media. The fractured were initially filled with a NAPL (octanol) and two fluids were used to displace the NAPL. The experiments show that the use of a viscosifer to increase the endpoint mobility ratio resulted in a significant improvement the sweep efficiency. The benefit of improved sweep efficiency is a significant increase in NAPL displacement, which is also observed in the experiments. These results were expected based on prior work in the petroleum industry for improved oil recovery, but to date have not been implemented for environmental remediation purposes.

In addition to the physical model results, computer simulations are presented that demonstrate the sensitivity of flow within fractured media to mobility ratio and to gravity number. First, the numerical model (UT Chem) was validated by duplicating the physical model. Once validated, the numerical model parameters were varied to explore both viscosity and density of the displacing fluid on the sweep efficiency.

The conclusions from the physical and numerical work is that the mobility ratio is a key consideration in both improving the delivery of remedial fluids in a fractured rock environment and when attempting to displace NAPLs from fractured rock. Density (i.e., buoyancy) effects are much less important in fracture flow when delivering remedial fluids. Finally, the value of a numerical simulator that can accurately depict flow within fractured rock is significant for two reasons: 1) our ability to duplicate physical experiments in the virtual world allowed us to repeat experiments and explore sensitivity to parameters and; 2) the ability for environmental practitioners to design and implement in–situ remedial systems within fractured rock can be accomplished with this numerical simulator.

Future work will entail simulation of horizontal wells installed in fractured media with the goal of optimizing the recovery of NAPLs. The horizontal wells will be configured in various patterns in order to explore the effect of both location and flow (producer vs. injector) on the recovery of dense and light NAPLs. This work has the long-term goal of a pilot test in the field at a contaminated bedrock site.