Contribution ID: **479** Type: **Oral Presentation**

Development of a new complex fluid for DNAPL recovery and nZVI delivery

Thursday, 3 June 2021 10:30 (15 minutes)

Soil contamination is one of the challenging problems that present risks for both the environment and the general population. Manufactured products made by chemical plants commonly contaminate aquifers and soils with miscible and immiscible organic liquids. In particular, in-situ remediation of soil contaminated with Dense Non-Aqueous Phase Liquids (DNAPLs) is of great interest. They represent one of the major pollutants found in France and other industrial countries (Colombano et al. 2020). Since DNAPL is denser than water, it commonly migrates vertically downward through the saturated zone until its displacement is hindered by low permeable formations where it starts to migrate laterally. These mechanisms will form DNAPL pools over the low permeability zones (Huling, 1991).
The displacement of DNAPL with low-density and less-viscous solutions is less efficient due to a complex interplay among viscous, gravity, capillary, and buoyancy forces. Therefore, it is nearly impossible to recover all DNAPL and avoid the back-diffusion effect (Seyedabbasi et al., 2012). Moreover, the classical pump and treat method is inefficient due to the low recovery yields below 60% (Colombano et al. 2020). Therefore, complex fluids, including foam and polymer solutions, were recently used (Maire et al., 2019; Omirbekov et al., 2020) for soil remediation. However, mobilization of DNAPL with less-dense fluid is doubtful because of higher buoyancy forces within the contaminated site. Consequently, the effect of denser polymer solutions on DNAPL mobilization is unknown. In this work, we investigate barite use to densify polymer solutions and apply this solution to transport nano-scale zerovalent iron (nZVI) to remediate soil contaminated with pure heavy chlorinated organic compounds.
To embody the concept, several environmentally-friendly polymers (guar gum, xanthan gum, and carboxymethyl cellulose) were experimentally studied to find their stability with barite (97% of BaSO4) and nZVI. The interfacial tension and rheological behavior of the solutions were examined. Furthermore, we carried out 1D porous column (filled with 0.5 mm glass beads) experiments to investigate the DNAPL displacement in porous media with the polymer, barite-polymer, and nZVI-barite-polymer solutions.
According to the decantation tests, the stability of nZVI and barite densified polymer solutions are ranked as the following: carboxymethyl cellulose > guar gum > xanthan gum. The column test shows that the polymer solution based on barite and carboxymethyl cellulose with the same density of DNAPL has the best recovery efficiency (up to 95%). Moreover, this solution allows delivering the nZVI while displacing the chlorinated compounds to reduce and degrade the DNAPL residual saturation.
Our results demonstrate the effectiveness of the new slurries for soils contaminated with DNAPL. Therefore, the newly developed solution can be directly injected into the DNAPL contaminated zones, improving the remediation rate and decreasing the economic cost. We anticipate that our research will constitute a starting point for developing new environmental fluids to remediate soils contaminated by DNAPL.

Time Block Preference

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

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Session Classification: MS18

Track Classification: (MS18) Innovative Methods for Characterization, Monitoring, and In-Situ Remediation of Contaminated Soils and Aquifers