Field Demonstration of Foam Injection to Confine a Source Zone of Chlorinated Solvents

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Background/Objectives. Mobility control emerges as a promising alternative technique to enhance the recovery of DNAPLs by using low mobility agent (i.e., high viscosity) such as polymers or surfactant-foam to improve the sweep efficiency of aquifers. One of the benefits of using foam in environmental remediation (ER) is its ability to act as a selective permeability reductive agent (Bertin, 1999; Kovscek, 2003; Bertin, 2017). The major objective of the presented study is to use foam as a blocking agent to confine a source zone of chlorinated solvents (mainly trichloroethylene [TCE]). The blocking ability of foam is used to divert the groundwater flow arriving at the right of the source zone. The second objective is to present tools that allow assessing, the reduction of the spread of contaminant into the aquifer.

Approach/Activities. Pre-generated foam were injected into six piezometers surrounding the identified source zone (area of the injection equal to 400 m^2). Injection lines were built in order to manage and record air/water/surfactant flow rate. Foam was injected continuously over 96 hours. To define foam effectiveness three approaches were used: Slug tests that give a local indication, fluxes measurement using passive flux meter (PFM) providing a global efficiency, while a pumping test was run in the confine area to define the extent and location of each foam zone. All results were consigned in a 2-D groundwater flow using MODFLOW, in order to fit the drawdown curve (pumping test). Transport model using MT3DMS code were then run to match the PFM results with the previous foam zone defined in the groundwater flow model.

Results/Lessons Learned. The first indication of the foaming performance is the increase of the injection pressure in all injection paths. For path 2, injection pressure increased during the first 12 hours before reaching a maximum of 2.55 bar. Subsequently, the pressure stabilized around 1.8 to 1.9 bar until the end of the injection period. Reduction factors of K higher than 100 were measured right after the foam injection indicating the presence of foam around the injection well. The persistence of foam was characterized by slug test measurements after 3 months with a reduction of K higher than 10. These measurements show the local efficiency of the foam injection but do not provide information about the radius of influence. Modelling step provided a good reproduction of the drawdown. The fitted zones radius ranged between 2.0 and 3.2 m. Calculated drawdowns only match observed data when foam zones were smaller than the estimation done with injected foam volume and with a very low hydraulic conductivity value (range from 9.2×10^{-9} to 1.0×10^{-10} $m.s^{-1}$). All monitoring wells recorded a decrease of chlorinated solvents fluxes ranging between 39 to 206 $mmol.m^{-2}.day^{-1}$ corresponding to a reduction factor of approximately 4.4. These results are confirmed by a modelling of the source dissolution with and without foam. The foam model was used to calculate the dissolved flux of CS delivered by the source zone. By only using the calibration obtained with pumping test data, the flux is reduced by a factor of 3.05 due to foam injection, which is close to flux measurements. Therefore, foam clearly acts as a hydraulic barrier and leads to the reduction of contaminant fluxes downstream to this area.