FIELD DEMONSTRATION OF SURFACTANT-ENHANCED DNAPL REMEDIATION -- CASE STUDIES

B. J. Shiau, M. A. Hasegawa
Surbec-ART Environmental, L.L.C.
D. A. Sabatini, R. C. Knox, Jeff Harwell
University of Oklahoma
Rafael Lago
Tetra Tech EMI
Contact Information: Phone: 405-364-9726 Fax: 405-364-9726, hasegawa@surbec-art.com

Three surfactant flushing field demonstrations were recently completed at different DNAPL-contaminated sites. Each site represents different contaminant and subsurface characteristics. Results from these demonstrations, Alameda Point, CA (formerly Naval Air Station Alameda), Spartan Chemical Company Superfund Site, MI, and Dover National Test Site, DE are presented. At each location, site-specific bench testing was used to select the optimal surfactant. In each case the surfactant system was designed to maximize solubilization without downward mobilization. In addition, process equipment was utilized to treat produced fluids for surfactant reuse and waste minimization.

Alameda Point

A picture of the site and the process equipment used at Alameda Point are shown in Figure 1. The main contaminants at Alameda Point were trichloroethylene and trichloroethane. Subsurface sediments consisted mainly of medium grain sands underlain by the bay mud. Partitioning interwell tracer testing was used prior to the demonstration to: 1) show that the recovery wells provided adequate hydraulic capture and 2) quantify pretest NAPL saturations. Five-pore volumes of surfactant solution were flushed through the DNAPL-impacted test area resulting in over 320 kg of recovered DNAPL and 95%+ mass reduction (refer to Figure 2). Contaminants were removed from the effluent stream using a combination of a proprietary liquid-liquid extraction process provided by Akzo Nobel and air stripping. Subsurface mass removal was determined using a combination of pre and post soil coring analysis, pre and post partitioning interwell tracer tests and mass removed as measured in recovered groundwater and product (refer to Table 1). As shown in Table 1, the predicted initial volume of DNAPL varied widely depending on the method used for evaluation. However, the post test analysis consistently indicated that the NAPL mass had been reduced substantially. Post remedial groundwater concentrations were reduced by 50%-80% corroborating the soil results. Estimated full scale cost analysis showed the technology could be implemented for 1/3 the cost of pump and treat.

Table 1: Results of Alameda Point performance evaluation

Evaluation Methodology	Pre-test Volume (gal)	Post-test Volume (gal)	Percent Removal
PITT			
2,4-DMP	100	<1.0	>99%
Hexanol	169	<1.0	>99%
Pentanol/ Heptanol	NA	3.17	NA
Coring	34.0	<1.0	>97%

Figure 1: Test site including mobile process equipment

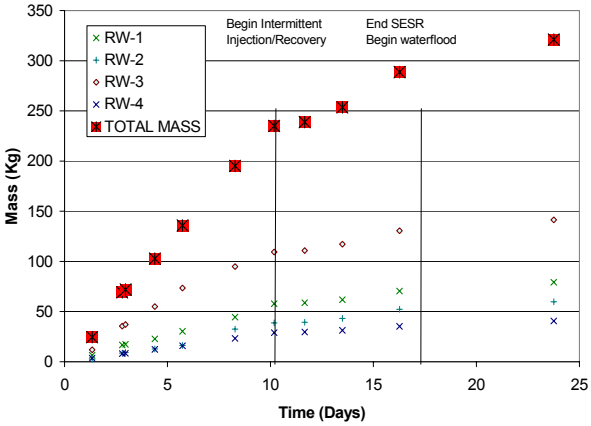

Figure 2: Cumulative TCE and TCA mass recovery (kg) from effluent during surfactant flooding at Alameda Point

Dover National Test Site

The surfactant flood conducted at the Dover National Test Site was conducted in a contained cell with a controlled release of PCE (refer to Figure 3). The objective was to remove the PCE using the designated technology. The soil matrix consisted of interbedded layers of fine sand and silt. The performance of the technology was evaluated using a combination of mass recovery as measured in the effluent, pre and post partitioning interwell tracer tests, and groundwater analysis. As can be seen in Figure 3, the well density within the cell is very high allowing for detailed analysis. Vertical circulation wells were used to distribute surfactant throughout the cell. The produced groundwater was passed through a packed tower air stripper where PCE was removed and recirculated within the test cells. Surfactant was added as required. Based on preliminary pre and post groundwater analysis, the concentration reductions range from 70 to 97% in 8 wells.

Figure 3: Test cell at Dover National Test Site

Spartan Chemical Superfund Site

The main contaminants at the Spartan Chemical site were methylene chloride, trichloroethylene, ketones (i.e., acetone) and BTEX. Although no NAPL was ever obtained from the site, high concentrations of contaminants were observed in groundwater and soils at depths of 70 feet below the water table. As a result, bench testing was conducted using simulated NAPL. Column test results showed that the selected surfactant solution, AMA (sodium dihexl sulfosuccinate) and SMDNS (alkylated naphthalene sulfonate) with sodium chloride as additives, was able to remove 95% of the trapped oil. The site sediments consisted of coarse grain sands. Prior to injecting surfactants, conservative tracer testing was conducted to ensure hydraulic capture of the injection/recovery system. Fluorescene was used as the conservative tracer and a total of 90% recovery was observed. Contaminant concentrations recovered during the tracer test were initially very high of which acetone was the highest starting at 560 ppm and dropping to 42 ppm prior to the injection of surfactants. Once surfactants were injected contaminant mass removal was increased by up to forty fold (refer to Figure 5). However, the peak concentrations during the surfactant flood did not reach the equilibrium levels observed at the beginning of the tracer tests. This is attributed to the high solubility of the ketones and alcohols allowing for a large amount of contaminant removal without the use of surfactants and a low NAPL saturation. Although surfactants showed an ability to substantially enhance the removal of contaminants, it appears that the more soluble NAPL constituents are already allowing for a large amount of NAPL mass to be removed through pumping alone.

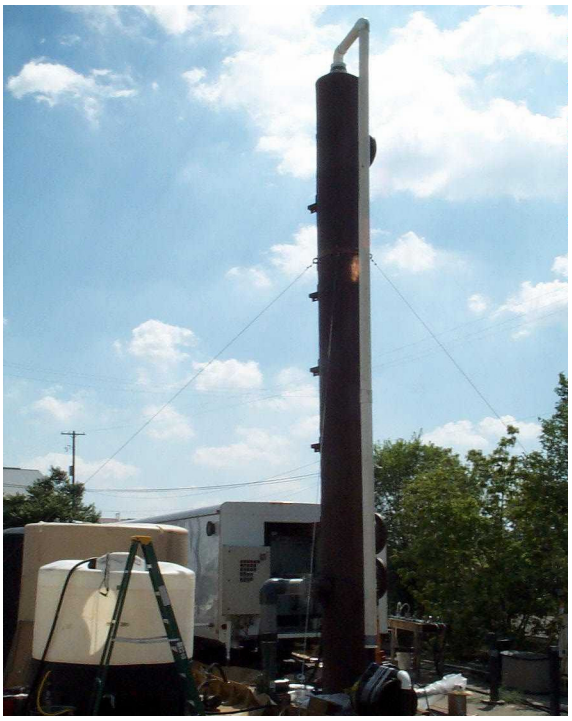

Figure 4: Spartan Chemical test site

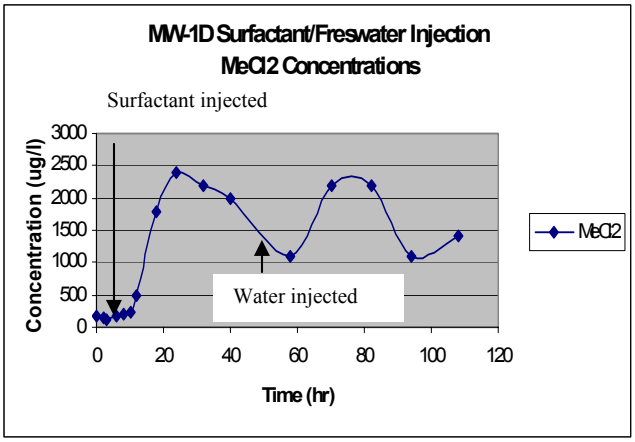

Figure 5: Methylene Chloride breakthrough in MW-1D at Spartan Chemical

These highly successful field demonstrations are all the more impressive given the widely varying site conditions which ranged from coarse sand (Spartan Chemical) to fine sand and silt (Dover AFB). Additional details on the site conditions, performance evaluation criteria, integrated processes used, cost comparisons and results are presented.