# Design and Implementation of Full-Scale In Situ Chemical Oxidation of PCE in Soil and Groundwater Using Surfactant-Facilitated Sodium Permanganate at an Urban Location

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**Background/Objectives.** Groundwater and soil at a one-third acre urban location (Site) is impacted with tetrachloroethene (PCE) and there are multiple lines of evidence indicating the likely presence of dense non-aqueous phase liquid (DNAPL). The Site is surrounded with commercial business and residences and therefore safety was a significant concern while implementing remediation. The highest concentrations of PCE detected are located under a municipal parking lot, however, the primary health threat posed by the Site has been the detection of elevated levels of PCE in the indoor air of three adjacent commercial buildings caused by the vapor intrusion pathway. The remedial objectives for the Site are to reduce PCE concentrations in soil and groundwater to below regulatory limits and thereby eliminate the threat posed by vapor intrusion. The remedial action selected was surfactant-facilitated in situ chemical oxidation (ISCO) treatment for unsaturated and saturated soil in hot spots, and ISCO for groundwater.

**Approach/Activities.** Sodium permanganate ($NaMnO_4$) was chosen as the oxidant due to its proven effectiveness against PCE and longevity; surfactant was selected to facilitate the desorption of DNAPL from soils. As part of the pre-design investigation (PDI), the following were evaluated: 1) permanganate native oxidant demand (PNOD); 2) laboratory column studies to screen surfactants and determine their effect on PCE mobilization, 3) bench reactor studies to determine oxidant demand due to surfactant presence, and 4) clean water pilot test to determine the aquifer capacity to accept injection water. Full-scale design consists of three rounds of injections with the first injections delivering approximately 51,000 pounds (lbs.) of $NaMnO_4$ (40% strength) and 2,000 lbs. of surfactant (35% strength) into the soils and groundwater. The first round of injections has been completed and oxidant and surfactant were delivered through 108 Geoprobe®-driven injection points.

**Results/Lessons Learned.** Results of the clean water gravity test indicated that gravity injection at the Site can be performed at rates of approximately 3 gpm per well. These data indicated that ISCO injections could be achieved during full-scale implementation with the use of minimal injection pressures, an important consideration in this urban setting. The PNOD test revealed an average oxidant demand of 1.7 g/kg soil, which is considered favorable for ISCO. Column testing revealed that the surfactant Calfax® 16L-35 (Calfax) at a 1 percent solution mobilized 54 percent of the PCE mass added to the soil, while a 5 percent solution mobilized greater than 95 percent. The bench reactor test demonstrated that $NaMnO_4$ could destroy PCE in the presence of the Calfax; at least 98 percent of the PCE added in the $NaMnO_4$ + surfactant reactor was destroyed within 7 days. These pre-design investigation results were critical in the preparing a full-scale design of the treatment remedy.
The first round of full-scale injections was carried out safely with no ISCO breakouts to the ground surface, utilities or basements of adjacent buildings, no safety issues or near misses, and no complaints from the nearby residents and business owners. Approximately 44,000 gallons of 5% to 20% $NaMnO_4$ were injected into the groundwater. The distribution of $NaMnO_4$

was monitored in groundwater using a visual field kit during injections, and at intervals of 1-month and 2-month post-injection. Results revealed adequate distribution of the oxidant in the targeted areas and that oxidant had dispersed under several impacted buildings via migration with groundwater. Preliminary results revealed that PCE concentrations in the most contaminated monitoring well at the Site had decreased by about 6-fold after two months following oxidant injections. Groundwater will be collected in the next several quarters and the data on PCE destruction will be presented. It is anticipated that a total of three rounds of injections will be required to remediate the Site.