INNOVATIVE TREATMENT OF NON-AQUEOUS PHASE LIQUIDS (NAPLS) USING SURFACTANT-ENHANCED IN-SITU CHEMICAL OXIDATION (S-ISCO®)

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Traditional ISCO methods have had limited success in degrading non-aqueous phase liquids (NAPLs) because of mass transfer limitations controlling the rate of dissolution of NAPL constituents into groundwater. In Situ Chemical Oxidation (ISCO) reactions predominantly take place in the aqueous phase in the subsurface. Treatability studies and field verification pilot-studies have been conducted to evaluate the effectiveness of a new type of Coelution Technology®, Surfactant-Enhanced In-Situ Chemical Oxidation (S-ISCO®), in reducing the amount of non-aqueous phase liquids (NAPLs) in soils. The S-ISCO® technology, patent-pending by VeruTEK Technologies, Inc., uses biodegradable, food-grade cosolvents and surfactants (VeruSOL®) (for example, coconut oil, castor oil and citrus extracts) to solubilize immiscible phase organic compounds into groundwater. Application of S-ISCO® with VeruSOL® destroys contaminants in-place using traditional ISCO processes, particularly activated persulfate. S-ISCO® involves coeluting both the cosolvent-surfactant mixture with the oxidant enabling simultaneous dissolution and oxidation. Selection of the specific VeruSOL® mixture is dependent on the nature of the NAPL components, particularly, the mole fractions and octanol-water partition coefficients (K_{ow}) of the individual organic compounds. The coelution involves controlling the rate of NAPL compound dissolution and the oxidation reaction rates. Laboratory treatability studies demonstrated that the solubilization reaction by surfactant and surfactant/cosolvent mixtures resulted in significant increases in dissolved phased COCs without mobilizing NAPL.

Soil column tests were run using homogenized soil from an MGP site and spiking the soil with DNAPL from the MGP site to approximate residual saturation with respect to MGP DNAPL. Various surfactants and cosolvent-surfactant mixtures were flushed through replicate columns. VOCs and SVOCs were periodically monitored in the column effluent using USEPA Methods 8260 and 8270. Results from the column tests are shown in Figure 1, in which the total effluent VOCs and SVOCs (in molar units) for each of the column run conditions, including a run in which Fe(II)-EDTA activated persulfate was flushed through a replicate soil column. It is evident that VeruSOL™-3 exhibited the greatest potential for solubilizing the MGP DNAPL compounds in comparison to the other tested surfactants and cosolvent-surfactant mixtures. The simultaneous addition of Fe(II)-EDTA activated persulfate to a column being flushed with VeruSOL™-2 reduced total effluent COCs flushed from the column by 87 percent.

A chlorinated solvent DNAPL was obtained from a site consisting predominantly of carbon tetrachloride and tetracholoethylene. An aliquot of the DNAPL was mixed with a suitable quantity of deionized water to determine the equilibrium solubility of the

individual compounds in the presence of the DNAPL. Results of the solubilization experiments in Figure 2 indicate adding a cosolvent-surfactant mixture significantly enhanced solubilization of the DNAPL compounds, in comparison to that solubilized in deionized water alone. Aliquots of the VeruSOL^{TM} enhanced solubilized DNAPL mixtures were then added to aliquots of a sodium persulfate solution and the bulk solution pH adjusted to greater than 12 using NaOH for an alkaline activated persulfate oxidation. These solutions were slowly mixed at 60 rpm on an orbital shaker table for 14 days and then VOC and SVOC concentrations measured using USEPA Methods 8260 and 8270. The overall removal of VOCs and SVOCs was calculated for each treatment condition and the results can be found in Figure 2. The T1 and T3 samples, which initially had 0.8 g/L and 4.3 g/L, respectively of VeruSOL^{TM}, had greater than 99 percent removals of VOCs and SVOCs after 14 days of treatment. The T7 sample that initially had a VeruSOL^{TM} concentration of 83.3 g/L and a much greater concentration of dissolved VOCs and SVOCs than the other vials had VOCs and SVOCs removals that were 94 percent and 76 percent, respectively.

Figure 1. MGP COC Removal in Soil Columns Flushed with Various Surfactant and Cosolvent-Surfactant Mixtures

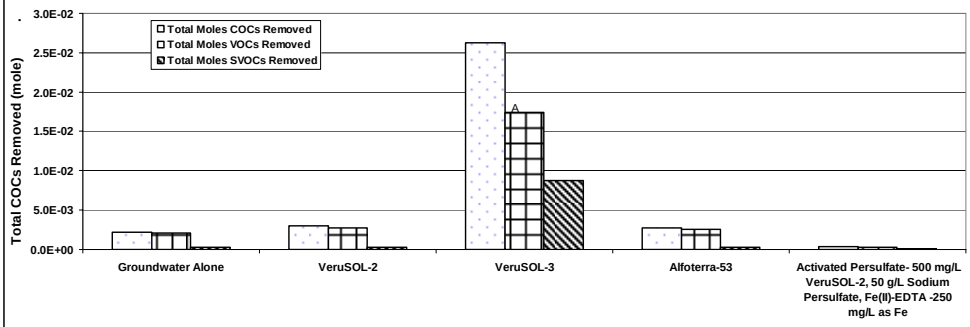
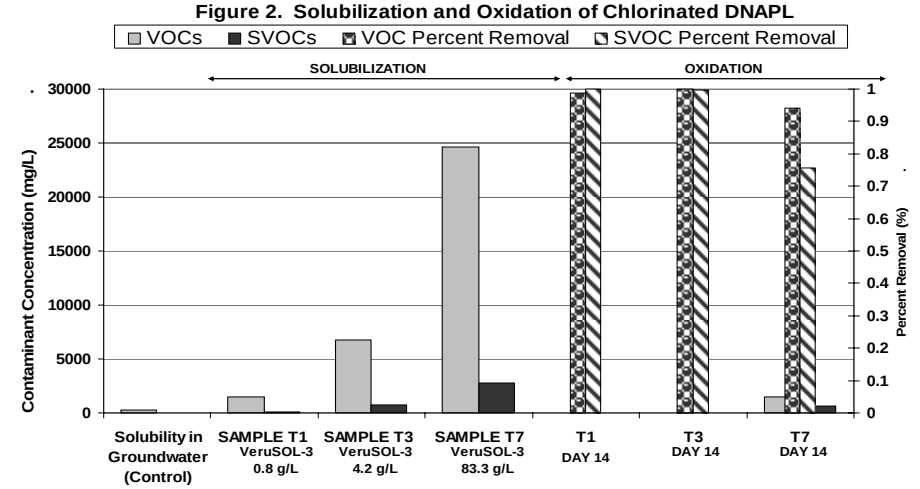


Figure 2. Solubilization and Oxidation of Chlorinated DNAPL



Notes: (1) Control consisted of solubilized DNAPL in water to reach saturation conditions.
(2) DNAPL is composed of Tetrachloroethene (PCE), Carbon Tetrachloride (CTC), Hexachlorobutadiene (HCBD), Hexachlorobenzene (HCB), Hexachloroethane (HCE), Octachlorostyrene (OCS), and Octachloronaphthalene (OCN).
(3) Aliquots of the VeruSOL-3 solubilized DNAPL chlorinated solvent (Samples T1-T3) were taken then oxidized using NaOH high pH activated persulfate