Coupling Surfactants with Permanganate for DNAPL Mass Removal: Coinjection or Sequential Application as Delivery Methods

Pamela J. Dugan, Carus Corporation, Peru, IL; Robert L. Siegrist, Colorado School of Mines, Golden, CO; Michelle Crimi, Clarkson University, Potsdam, NY

Surfactant-Enhanced In Situ Chemical Oxidation

• Surfactants greatly enhance DNAPL solubility
• Oxidants destroy dissolved phase contaminants but not very effective for DNAPL removal
• Pair oxidant with surfactant so as rate of surfactant solubilization increases, the rate of mass destruction increases

Objective

2-D flow-through cell experiments were performed coupling surfactant-enhanced aquifer remediation (SEAR) with in situ chemical oxidation (ISCO) to achieve significant mass removal of PCE DNAPL.

Two delivery methods were evaluated:
1) Coinjection of surfactants (to solubilize PCE DNAPL) with permanganate (to oxidize dissolved phase PCE) in a single step
   • Potential benefit:
   • Reach target mass depletion goals faster
   • Decreased above-ground treatment of fluids
2) Sequential Application: Surfactant flush followed by ISCO with permanganate as a polishing step
   • Potential benefit:
   • SEAR for treatment of high permeability zones
   • ISCO as polishing step treats low permeability zones

Methods

Previous batch screening tests determined permanganate compatible surfactants

• Two 2-D flow-through cells packed identically (PV = 1.5 L)
• PCE DNAPL added to each cell (2-4 g)
• PCE, chloride, and KMnO₄ samples taken from 8 point sampling ports and effluent

Remediation Goal

• Remove >96% PCE DNAPL mass using lower concentrations of surfactants and oxidants with less than 1PV of flushing
• Cells extracted in batch at conclusion of experiments to determine mass of DNAPL removed

Results

Pre-Rush

During Rush

3-Days post Rush

Transmit 1

Pre-Rush

During Rush

3-Days post Rush

Concluding 2-week period all ports +H I G F E D C B A

Flow

H

I

G

F

E

D

C

B

A

Conclusions 2-week period all ports +H I G F E D C B A

Performance Assessment

• Coinjection – 99.8% DNAPL Mass Removal
• Sequential Application – 100% DNAPL Removed
• For both delivery methods, achieved remedial goal of removing > 90% DNAPL mass using low concentrations of amendments with < 1 PV of flushing