Polymer-Enhanced Subsurface Delivery and Distribution of Permanganate

In situ chemical oxidation (ISCO) using permanganate is a well-established remediation technology with numerous field applications that have demonstrated success in terms of contaminant destruction and ability to achieve cleanup goals. However, some permanganate ISCO sites have had challenges with treatment efficiencies due to nonuniform oxidant delivery caused by zones of low permeability media and management of manganese dioxide (MnO₂) particles, a byproduct of the reaction of permanganate with organic contaminants and naturally reduced subsurface materials. The MnO₂ particles have the potential to deposit and impact flow in and around the well screen, filter pack, and the surrounding subsurface formation (figure 1).

The Challenge
Site heterogeneities challenge all in situ treatment technologies involving fluid delivery

There is no currently implemented approach for managing these ISCO challenges

Figure 1: Potential Effects of MnO₂ Particle Deposition on Permanganate ISCO

Previous laboratory research efforts investigated combining water-soluble polymers with permanganate ISCO to: (1) modify fluid viscosity, thereby allowing the permanganate/polymer solution to enter lower permeability zones and, (2) prevent MnO₂ particles from agglomerating and forming large particles which can settle/deposit and potentially impede flow.

A cooperative technology field demonstration was conducted through the Environmental Security Technology Certification Program (ESTCP) at Marine Corps Base Camp Lejeune Site 88 to investigate the use of water-soluble polymers to enhance subsurface delivery and distribution of permanganate (Project ER-0912) (figure 2).
The demonstration is led by a collaborative team from Clarkson University, the Colorado School of Mines, and CH2M HILL. The primary objectives of this field effort were to incorporate water-soluble polymers in the permanganate flushing solution in order to: (1) improve the sweep efficiency of permanganate through heterogeneous media containing lower permeability media using the polymer xanthan gum and (2) control MnO$_2$ particle deposition to improve oxidant delivery and flow, thereby enhancing contaminant destruction, using sodium hexametaphosphate (SHMP). The contaminant of interest was tetrachloroethylene (PCE) from former dry cleaning operations.

Two plots were used for the demonstration – a permanganate only "control" plot, and a permanganate + SHMP + xanthan "test" plot. After careful site characterization and site-specific treatability evaluations were completed, the treatment solutions were delivered to an injection well installed in the center of each respective plot at a rate of approximately 10 gallons per day for 5 days (figure 3).
The permanganate concentration was 5,000 mg/L (delivered as RemOx® L ISCO reagent, sodium permanganate), the SHMP concentration was 5,000 mg/L, and the xanthan gum concentration was 800 mg/L. Water quality was monitored before, during, and after injection in two multi-level sampling (MLS) wells (4 levels each) located 15' from the central injection point in the control and test plot. Measured parameters include PCE, pH, oxidation-reduction potential (ORP), solids, major cations and anions, and total organic carbon (TOC). After the 5 day injection period, twelve soil cores were collected within the control and test plots. PCE, pH, ORP, TOC, cation exchange capacity, and manganese speciation were measured in each core and compared to pre-treatment values measured in cores collected for the injection and monitoring wells.

Preliminary results to date show that the use of polymers with permanganate for enhancing movement into lower permeability zones and for MnO₂ management is promising. Post-treatment monitoring is ongoing. Data analysis is also ongoing and will include an assessment of the biogeochemical impacts of the combined approach.

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Additional information will be included in a Carus Remediation Technologies Newsletter in 2011.