United States Environmental Protection Agency

Technology Update #2: Nanotechnology

Nease Chemical Site
Columbiana County, Ohio June 2007

More information

If you are interested in finding out more about the Nease Chemical cleanup project, here are resources:

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On the Web:
www.epa.gov/region5/sites/nease/

You may view site-related documents at the following locations:

EPA Region 5 Records Center
77 W. Jackson Blvd.
Chicago, Ill.

Ohio EPA Northeast District Office
2110 E. Aurora Road
Twinsburg, Ohio

Lepper Library
303 E. Lincoln Way
Lisbon, Ohio

Salem Public Library
821 E. State St.
Salem, Ohio

In 2005, U.S. Environmental Protection Agency selected a remedy to address contaminated soil, ground water and source areas at the Nease Chemical Superfund site which includes the use of nanotechnology – nanoscale zero-valent iron (NZVI) – to remediate VOCs in ground water. Site owner Rutgers Organics Corp. and its primary consultant Golder Associates have been conducting a pre-design investigation to support the engineering design plans needed for the complex and innovative project. Ohio EPA is providing additional oversight. The work started in June 2006 and includes a NZVI treatability study.

NZVI was selected to treat highly contaminated ground water in the fractured sedimentary bedrock near the source. Total VOCs exceed 100 mg/L near the source, consisting primarily of chlorinated ethene and ethane compounds, as well as chlorobenzene and benzene. DNAPL has been observed in wells near the source areas.

NZVI treatment at the Nease site will involve the injection of an iron-water slurry through wells into the contaminated aquifer. The small iron particles (less than 100 nanometers) have a large surface area compared to volume and provide a reactive surface that breaks down contaminants through oxidation-reduction reactions. Contaminants are reduced to non-toxic end products (e.g., ethane). The particles will remain suspended for some time and flow with the ground water, traveling away from the injection point to create a diffuse treatment zone. Eventually, the particles lose their reactivity and settle out.

NZVI Treatability Study

The NZVI treatability study is being conducted in two phases – a bench scale study and a field pilot test.

The bench scale study occurred in summer of 2006. Ground water was collected from a highly contaminated site well, and laboratory studies assessed different formulations of NZVI and a range of NZVI concentrations for rate and effectiveness of treatment of the chlorinated VOCs found on-site. The bench study also evaluated the effect of NZVI on non-chlorinated VOCs and assessed byproduct generation. Major findings are discussed below.

The field pilot study started in November 2006 to confirm in-situ treatment effectiveness and support design of the full-scale treatment approach. One hundred kg of NZVI in 2,665 gallons of clean water was injected into a highly contaminated portion of the aquifer. The iron was injected in batches containing powdered soy as an organic dispersant (20 percent by weight of NZVI), and most batches contained a small amount of palladium (1 percent by weight). Four wells installed at close range were monitored

during injection for water levels and geochemical parameters. Chemical monitoring has been conducted periodically for six months. Preliminary results are discussed below.

Major Findings of Bench Scale Study

The bench scale study showed promising results. Bimetallic particles – nanoscale iron coated with a small amount of palladium – worked better in the short term than iron alone. NZVI without palladium showed only partial treatment within two weeks. Rapid reductions in contaminant concentrations were seen with mechanically produced NZVI at 2 g/L with 1 percent palladium (see Table 1). No chlorinated byproducts were detected. However, benzene was not adequately treated and was produced as a byproduct by reduction of 1,2-dichlorobenzene.

Contaminant	Initial Conc. (ug/L)	Reduction
Tetrachloroethene (PCE)	82,000	98%
Trichloroethene (TCE)	21,000	99%
cis-1,2-Dichloroethene (cis-DCE)	11,000	97%
1,2-Dichlorobenzene	15,000	"complete"
Benzene	7,000	increased

Table 1: Bench test reductions within two weeks using NZVI at 2 g/L with 1% palladium.

Preliminary Results of Field Pilot Study

The field pilot study was designed based on the results of the bench test. Preliminary results are promising. Geochemical and chemical data showed that all of the monitoring wells (located 10 to 20 feet from the injection well) were being influenced. After four weeks there were substantial reductions in all wells of PCE (38 to 88 percent of the initial well concentration – see Figure 1) and TCE (30 to 70 percent of the initial well concentration). Non-toxic end breakdown products (methane, ethane, ethane) increased. However, cis-DCE was produced, likely by partial dechlorination of parent compounds (see Figure 2). Samples taken after eight and 12 weeks (not shown on figures) appear to show stable or increasing concentrations, which would be expected because the upgradient source has not yet been treated.

The field pilot resulted in several "lessons learned." Even in a relatively small area like the pilot study, aquifer heterogeneity can be substantial. Aquifer testing was useful and resulted in a change to which well was used for injection and an additional monitoring well was installed. The time required to inject the NZVI was significantly longer than planned and several adjustments were made in the field to try to improve the injection rate.

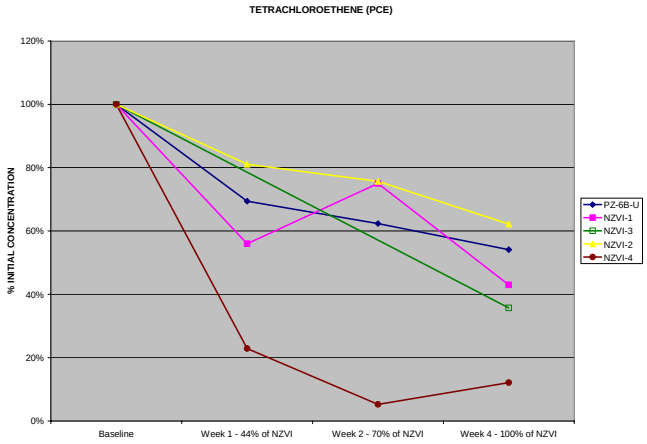

Figure 1: % Initial PCE Concentration Over 4 Weeks.

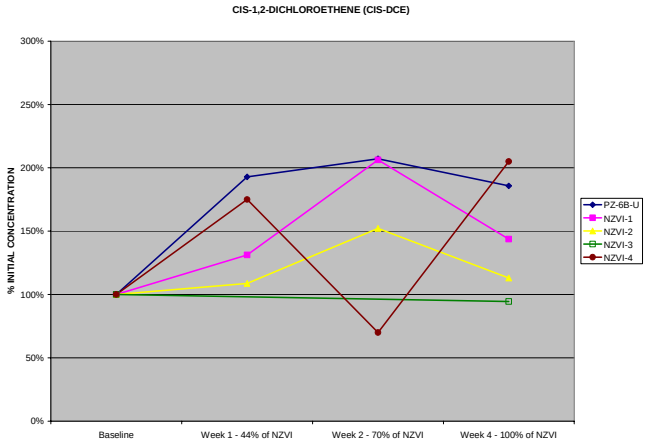

Figure 2: % Initial cis-DCE Concentration Over 4 Weeks.

Next Steps

The final monitoring results of the NZVI field pilot study will be evaluated in the summer. Because benzene was not degraded by the NZVI, biotreatability pilot work will occur in 2007. Enhanced biotreatment will be considered as a "polishing" step to address benzene expected to remain after NZVI treatment. Results from the treatability study will be used to design the full-scale system. A technical memorandum summarizing all NZVI work will be available later in 2007.