Limitations and Lessons Learned from Applying In Situ Chemical Reduction to Treat VOCs and Metals in a Geochemically Complex Aquifer

Thomas J. Patterson, P.E. (tpatterson@rouxinc.com)
(Roux Associates, Inc., Logan Township, NJ, USA)
Ravi Srirangam, P.E., Ph.D (PeroxyChem, LLC, Philadelphia, PA, USA)
Leo M. Brausch, P.E. (Brausch Environmental, LLC, Charlotte, NC, USA)

Background/Objectives. In situ chemical reduction (ISCR) is the selected remedy to supplement and eventually supplant a 22-year old groundwater recovery and treatment system (GWRTS) for accelerating the remediation of volatile organic compounds (VOCs) and metals (primarily beryllium and chromium) in groundwater at a New Jersey Pinelands Superfund Site. ISCR bench-scale and pilot testing programs were conducted using various substrates and buffering materials to evaluate ISCR effectiveness in an aquifer with naturally acidic pH (4.0 to 5.5 Standard Units [SU]), high sulfate levels (up to 140,000 micrograms per liter [µg/l]), and hydraulic challenges due to naturally elevated and GWRTS-induced groundwater velocities. The significant compounds of concern (COCs) consist of: chlorinated ethanes, chlorinated ethenes; ethylbenzene; beryllium; and chromium. As a result of residual source area impact and various groundwater hot spots where COCs exceed the applicable or relevant and appropriate requirements (ARARs), projected timeframes for meeting ARARs using the current GWRTS remedy present overall project end-point and cost concerns that can potentially be addressed using ISCR.

Approach/Activities. A phased pilot-scale approach was implemented in four distinct groundwater impact areas (one residual source area and three hot spots) to fully evaluate the best means to implement ISCR as a site-wide remedy given the aggressive geochemical and hydrogeologic challenges at the site. To design an ISCR pilot test, initial ISCR bench-scale testing was conducted using EHC®-Metals supplemented with pH buffers. Initial ISCR pilot testing consisted of injecting a similar ISCR substrate without added sulfate (EHC® in lieu of EHC®-Metals because of naturally elevated sulfate concentrations in site groundwater), along with pH buffering material (magnesium hydroxide) and bacteria inoculum (KB-1®) in three targeted areas of the site (the single source area and two downgradient hot spots). After two years of post-injection groundwater monitoring, COCs in some areas were reduced using various ISCR-driven processes (both biotic and abiotic) but some results were inconclusive primarily due to pH impact, hydraulic influence, and preferential reduction of VOCs over metals. In order to further evaluate ISCR and to specifically address metals, a formulation of ZVI and reducing agents (i.e., MetaFix®) was bench tested and a second pilot test was completed involving: EHC® re-injection in two previously pilot tested areas with increased pH buffering, bacteria inoculation, and modified GWRTS operation for improved hydrogeologic control; and MetaFix® injection in a metals-specific hot spot.

Results/Lessons Learned. Initial ISCR bench-scale and pilot testing provided mixed but very useful ISCR results regarding: geochemical conditions; pH buffering; influences from hydrogeologic conditions; and biotic/abiotic reduction, all of which proved useful in subsequent ISCR testing. A comparison of the various ISCR and ancillary remedial control approaches and their effectiveness with respect to observed ISCR processes and COC mass reduction will be presented. Specific lessons learned to be presented include: optimizing pH buffering to promote ISCR; effectively utilizing natural sulfate conditions as a positive factor for ISCR; the importance of hydrogeologic control through ISCR treatment zones; and overcoming geochemical limitations to address a mixture of VOCs and metals in a high mass flux scenario.