Zero-Valent Iron PRB Application Expands to Arsenic Removal

CLU-IN Resources

The State Coalition for Remediation of Drycleaners has compiled detailed technical profiles on remediation projects underway or completed at more than 100 sites throughout the U.S. The profiles are available online, along with related information on federal policies, state drycleaner programs, and technical reports, through CLU-IN's "Initiatives and Partnerships" at http://www.cluin.org or directly from the coalition at http://drycleancoalition.org.

TThe U.S. EPA Office of Research and Development's National Risk Management Research Laboratory (NRMRL) and Region 8 have begun evaluating the performance of a pilot-scale permeable reactive barrier (PRB) to treat arsenic-contaminated ground water at the East Helena Superfund site near Helena, MT. High ground-water flow rates coupled with high arsenic concentrations required the barrier design to involve wider dimensions in the path of ground-water flow than most PRBs currently in operation. Barrier construction also was challenged by the presence of some boulders in the subsurface, requiring use of large excavation equipment. Preliminary results indicate that arsenic concentrations as high as 20 mg/L in ground water entering the PRB are reduced to concentrations below 10 µg/L within the barrier. Concentration reductions downgradient of the PRB are anticipated after construction impacts on the treatment system subside and the ambient ground-water flow system is re-established.

Primarily due to smelting activities over the past century, arsenic in ground water at the East Helena site exists in the redox states of arsenite (As^{3+}) and arsenate (As^{5+}). The target arsenic plume is approximately 450 feet wide and extends 2,100 feet downgradient from the primary source of subsurface contamination. The site is underlain by alluvial deposits of cobble mixed with varying proportions of fine to coarse-grained sand to a depth of 48 feet below ground surface (bgs). The water table is 30 feet bgs. Only ground water within the the alluvial deposits and not the underlying volcanic tuff was found to be contaminated. Ground-water flow varies from about 0.5 to 3.0 ft/day according to the hydraulic properties of the aquifer materials and the prevailing hydraulic gradient.

NRMRL conducted batch and column studies on simulated ground water in 2003 to assess the effectiveness of zero-valent iron (ZVI) for arsenic remediation, determine arsenic removal mechanisms, and evaluate potential use of a ZVI barrier in long-term remediation of arseniccontaminated ground water. Prior to these studies, ZVI was used more commonly to treat metals and halogenated organic solvents. Study results showed that arsenic removal is a twostep reaction with an initially rapid removal of arsenite (10-fold within 50 hours) followed by a slow removal process that involves formation of smaller amounts of As^{5+}. Additionally, analysis of surface precipitates indicated that As^{3+} uptake by carbonate green rust and other iron-corrosion products may play a major role in the treatment process. The overall removal capacity of ZVI was estimated at 7.5 mg arsenic/g iron.

Installation of the PRB was completed over five days earlier this spring. Heavy excavation equipment was used to construct a 6-foot-wide and 46-foot-deep trench running 30 feet in length perpendicular to the plume (Figure 1). During excavation, biopolymer slurry was used to stabilize the walls of the trench. Approximately 175 tons of ZVI filings were added to the trench through the biopolymer slurry using tremie equipment to achieve an (upper) depth of 25 feet bgs, 5 feet higher than the average ground-water level. The remainder of the trench was filled with coarse bedding sand.

Figure 1. Construction of the extensive PRB trench at the East Helena site required use of a 50-foot-high excavator equipped with a long-reach arm and a 3-foot-wide bucket.

A network of fully screened, short-screen, and multi-level wells, including 25 within the trench itself, will be used to monitor performance of the PRB. In addition, an in-situ flow sensor was installed to collect information on ground-water flow direction and velocity within the PRB. The first round of monitoring occurred in June 2005, 30 days after treatment began. Results showed arsenic concentrations below 10 µg/L in ground water within the barrier. Analysis of ground water within the PRB showed expected trends in pH, oxidation-reduction potential, and ferrous iron concentrations typical for ZVI systems.

Data analysis is underway for the second round of monitoring, which was conducted last month. Evaluation of the pilot-scale PRB will continue for two years to determine its long-term success in reducing arsenic concentrations to levels near the maximum contaminant level (MCL) of 10 µg/L. If successful, the PRB could be extended an additional 450 feet in length to capture 100% of the arsenic plume. The pilot project shows that the full-scale system likely should employ variable PRB thicknesses to effectively deal with variable arsenic concentrations across the plume width. Region 8 estimates a construction cost of $325,000 for the existing pilot-scale system.

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