Coupling Hydraulic Fracturing with Bioremediation for Treatment of Chloroethenes and 1,4-Dioxane in Low-Permeability Formations

Drew Baird (dbaird@frx-inc.com) (FRx, Inc., Charlotte, NC, USA)
Chapman M. Ross (FRx, Inc., Arlington, MA, USA)
Michael Klosky (ECC, Burlingame, CA, USA)
Andrew Lorenz (Arcadis, Novi, MI, USA)

Background/Objectives. Hydraulic fracturing is an established technology for delivery of amendments into low-permeability and heterogeneous formations. It has been used since the early 1990s to support a wide range of remedial approaches for treatment of chlorinated volatile organic compounds, petroleum hydrocarbons, metals, and 1,4-dioxane in soil and groundwater. Sand-filled fractures are useful for enhancing fluid delivery in low-permeability settings where fluid distribution is limited by low mobile porosity. Here we present the remedial approach and performance monitoring results for two full-scale bioremediation projects where sand-filled fractures enhanced fluid delivery for treatment of chlorinated ethenes (CEs) and 1,4-dioxane.

Approach/Activities. At Lake City Army Ammunitions Plant (LCAAP) in Missouri, chlorinated ethenes in fine-grained fluvial deposits at concentrations up to 278,000 µg/L total CEs were discharging from a solvent pit source. Over six years of operation, gravity fed injections of molasses solution to conventional injection wells were unsuccessful in distributing the amendment due to flowrate limitations. Total injection volumes for these annual events ranged from 1,700 to 3,600 gallons of a 4% (by wt.) molasses solution injected over eight months, and these volumes were unsuccessful at supporting anaerobic reductive dechlorination. A controlled hydraulic fracturing program implemented in late 2015 included the creation of 38 sand-filled fractures at 10 injection wells in a barrier configuration. In a two-week period, 7,200 gallons of emulsified vegetable oil (EVO) were gravity fed into the hydraulic fracture-enhanced wells.

Sand-filled fractures were also utilized at a former manufacturing facility in Michigan to treat a large 1,4-dioxane plume in weathered sedimentary bedrock via biosparging. A 2016 pilot test using conventional wells did not achieve consistent distribution of biosparging fluids. In 2017, a pilot test demonstrated that wells connected to sand fractures exhibited higher specific capacity, greater radius of influence (ROI), and improved 1,4-dioxane treatment. A full-scale fracturing project implemented in early 2019 involved fracturing in 48 biosparge wells arranged in four linear arrays transecting the plume. Operation of the biosparge system began in mid-2019.

Results/Lessons Learned. Sand-filled fractures increased the specific capacity of wells at both sites. At LCAAP, the average capacity of fracture-enhanced wells was 37 times that of conventional wells. The fracture-enhanced biosparge wells at the Michigan site increased biosparge well ROI (>15 feet in fractured wells versus <10 feet in conventional wells) and flow rates (5 SCFM versus 2 SCFM) at lower pressure (<10 PSI versus 20 to 30 PSI). System operation and maintenance optimization (e.g., lower energy use, less propane) afforded by the fracture-enhanced wells yielded cost savings of an estimated $400,000. The larger ROI and consistent distribution of fracture-enhanced wells resulted in the reduction in the magnitude and extent of the contaminant plumes at both sites. Post-injection groundwater data from LCAPP demonstrate an anerobic geochemical shift and reductions in CE concentrations of greater than 99% compared to baseline. As of 2021, average concentrations of 1,4-dioxane at the Michigan site have decreased by 76% to 86% in the near-source area and 83% to 93% in the distal plume area.