Full-Scale ERD and Bioaugmentation in Deep Groundwater Using New Reducing Agent to Create Anaerobic Water

Joy Su (jsu@ekiconsult.com), Earl James (ejames@ekiconsult.com),
Jessica F. Daugherty (jdaugherty@ekiconsult.com), and ***Karen A. Gruebel***
(kgruebel@ekiconsult.com) (EKI Environment & Water, Inc., Burlingame, California, USA)

Background/Objectives. A 3-acre Site located in the San Francisco Bay Area is impacted by chlorinated volatile organic compounds in shallow and deeper groundwater, primarily tetrachloroethene, trichloroethene (TCE), and their associated daughter products. The highest concentrations of TCE in deeper groundwater (20 to 50 feet deep) ranged from approximately 10 to 50 milligrams per liter (mg/L). Full scale in situ enhanced reductive dechlorination (ERD) was implemented for the shallow groundwater in 2013 and for the deeper groundwater in 2016. Prior to ERD injection activities, a complete pathway for reductive dechlorination of PCE and TCE to ethene was not present in deeper groundwater; as such *Dehalococcoides* (DHC) microbes were also injected. A new reducing agent in development during that time, Newman Zone® Oxygen Scavenger (OS), was used to create large volumes of anaerobic water quickly to allow for concurrent injection of ERD amendments and DHC to increase injection efficiency. This presentation focuses on the implementation and status of ongoing in situ ERD in the deeper groundwater at the Site.

Approach/Activities. The full-scale deeper groundwater remediation implementation was conducted in three phases during August 2016, November 2016, and May 2017. The first two phases included injection of 61,500 gallons of a diluted solution of nonionic buffered Newman Zone® (an emulsified vegetable oil) with Vitamin B12, Neutral Zone® (a carbonate buffer), baking soda (calcium carbonate), and DHC microbes at 98 direct push injection points across approximately 0.8 acres of the Site. The third phase of injection was a supplemental carbonate buffer injection used to mitigate low groundwater pH values.
To simultaneously inject amendments and the DHC augmentation, a large volume of anaerobic dilution water was required. Reagents/process considered to create the anaerobic water included: sodium ascorbate, zero valent iron, organic amendment (e.g., oil, lecithin), and nitrogen sparging. A relatively new product on the market, OS, which includes iso-ascorbate, buffer and chelated metal catalyst, was used to create anaerobic water. Batches of anaerobic water were created in volumes of approximately 4,000 gallons. Dissolved oxygen (DO) concentrations measured with a Clark-DO probe dropped from approximately 8 mg/L to 2.0 mg/L in 30 minutes and was not detected in approximately 60 minutes. Oxidation-reduction potential (ORP) dropped from approximately 8 millivolts (mV) to -25 mV in 30 minutes and -100 mV in 60 minutes.

Results/Lessons Learned.

- Approximately 6 months after the first two phases of injection, concentrations of TCE in deeper groundwater decreased by up to three orders of magnitude, and total molar concentrations of TCE and daughter products decreased by up to two orders of magnitude.
- Appropriate DO and ORP levels were created in the anaerobic dilution water to maintain the viability of DHC during mixing of DHC and other amendments during injection.
  - There were significant increases in DHC and TCE Reductase within 30 days of injection, increasing from 3.04E+01 to 1.08E+03 cells per milliliter (cells/mL).
  - There were significant increases in VC reductase within 60 days of injection, increasing from <5.00E-01 to 2.34E+02 cells/mL.

· OS was easy to use and quickly created anaerobic dilution water that could be used within 3 hours, which increased the efficiency of injection operations.