Client
Former Electronic Manufacturing Facility

Scope of Services
In-situ Remediation

In-Situ Groundwater Remediation Pilot Study

Former Electronic Manufacturing Facility

Massachusetts

Client: Manufacturer of Industrial Products

Performance Period:

- 2005 to 2007

Project Goal:

- Evaluate application of zero-valent iron to treat chlorinated volatile organic compounds in groundwater.
- To achieve closure of all environmental issues within 10 years.

ARCADIS Strategy:

- In-Situ treatment of chlorinated volatile organic compounds (VOCs) in source area through injection of zero valent iron (ZVI)
- Observation and monitoring of effects at downgradient locations
- Continued operation of existing pump and treat system to maintain hydraulic control at Site

Project Accomplishments:

- Completed In-Situ Pilot Study Using PolyMetallix nano-scale ZVI (www.polymetallix.com)
- Complete reduction of TCE concentrations to non-detect levels at a location 55 feet downgradient of the injection well
- Measured reduction of TCE concentrations ranging from approximately 70% to 95% at the injection well and adjacent monitoring well in source area

Picture 1: PolyMetallix nZVI

The Challenge

A manufacturer of industrial products has contracted ARCADIS to implement a Firm Fixed Price, Performance-Based, groundwater remediation project at a former electronic manufacturing facility in Massachusetts. The project is focused on the in-situ treatment of chlorinated volatile organic compounds (VOCs) detected in groundwater using innovative technologies. The goal of the project is to achieve closure of all environmental issues at the Site within 10 years (i.e., maximum contaminant levels [MCLs] for groundwater).

The primary constituents of concern (COCs) in groundwater include trichloroethene (TCE) and lesser amounts of degradation by-products such as dichloroethene (DCE). Groundwater occurs in fractured granite bedrock underlying the Site. Concentrations of

TCE in bedrock monitoring wells have been recently detected as high as 2,430 micrograms per liter (µg/L). An existing groundwater pump and treat system was previously installed at the site to treat the source area and to maintain hydraulic control and to protect a nearby municipal supply well. However, after over ten years of operation, little progress has been made in restoration of the Site.

The Approach

The remedial strategy developed by ARCADIS involves the in situ treatment of TCE in the source area through the injection of PolyMetallix nano-scale zero-valent iron (nZVI), manufactured by Polyflon, a Crane Co. company. A pilot study of this technology was performed during 2005.

Picture 2: Mixing nZVI Slurry

Overview of ZVI Technology

Zero Valent Iron (ZVI) is added to the subsurface as an abiotic electron donor to promote the reductive dehalogenation of the chlorinated VOCs in a direct chemical reaction with iron. This reaction results in the corrosion of the iron particles, removal of chlorine atoms from the VOC molecule, and produces chloride ions and innocuous by-products such as ethane, ethene, acetylene, and carbon dioxide. In this process, ZVI promotes the complete dechlorination of CVOCs without the buildup of intermediate degradation products such as vinyl chloride. The ZVI (Fe^0) is oxidized to ferrous (Fe^{2+}) and then ferric (Fe^{3+}) iron in the groundwater system, and is then typically removed from the groundwater through the formation and precipitation of iron hydroxides and, ultimately, iron oxides.

The ability to place elemental iron into the subsurface for the purposes of groundwater remediation is limited by the size, and correspondingly the mobility, of the iron particles. Standard ZVI particle sizes are generally larger than the pore throats in the aquifer matrix, requiring direct physical emplacement techniques. However, the advent of new elemental iron manufacturing techniques has produced iron particles as small as 10^{-7} meters in diameter (nano-scale). This nano-scale ZVI (nZVI) can be directly injected into the aquifer and overcome the physical limitations of direct subsurface placement of larger materials.

A smaller particle size also contributes to a dramatic increase in the reactivity of the iron due to the much larger surface area per unit weight of material. The small size of the nZVI increases the reaction rate by increasing the surface area of the ZVI that is available to participate in corrosion and contaminant reduction chemical reactions

ZVI Injection

For the pilot test, an initial injection of 100 pounds of the PolyMetallix nZVI was mixed with approximately 600 gallons of extracted and treated groundwater and injected into a bedrock well within the source area at the Site. The nZVI mass was injected into the bedrock fracture zones at a dose proportional to the level of VOCs detected in groundwater. A vertical VOC distribution profile was determined at the injection well using passive diffusion bag (PDB)

sampling techniques throughout the borehole. The nZVI suspension was injected into the fractured bedrock using a double packer system at injection pressures of between 170-200 pounds per square inch (psi) to enhance distribution of the nZVI into the aquifer.

Project Highlights: nZVI Remedy for Groundwater

Picture 3: nZVI injection

The Site groundwater data collected after the field injection of nZVI indicated an initial 95% reduction in TCE at the injection well and an adjacent well located approximately 15 feet from the injection well. Since the injection event, the TCE concentrations in the injection well have rebounded upwards. This result was as expected, due to migration of impacted groundwater from upgradient areas. However, the results suggest a net 70% long-term reduction of TCE as compared to pre-injection levels. The TCE concentration, in a downgradient location, was reduced from 123 ug/L (prior to injection) to non-detectable concentrations. A temporary rise in pH, potentially the result of the fast corrosion of the nZVI particles, was also observed at a downgradient monitoring well located approximately 55 feet from the injection well. Results to date have not demonstrated reduction in TCE concentrations at further downgradient monitoring locations. Figure 1 shows the TCE concentration trends before and after the nZVI injection for select monitoring wells within the target treatment area.