

## Low-Pressure Injection of a Mixed Suspension of Colloidal ZVI and EVO into Fractured Clay at Niagara Falls ARS

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**Background/Objectives.** Metal-assisted bioremediation uses a combination abiotic and biological reductive dechlorination processes to accomplish the accelerated in situ remediation of soil and groundwater containing PCE, TCE and daughter products. Historically, metal assisted bioremediation projects have required the use of relatively large iron products that are difficult to emplace uniformly into contaminated groundwater using direct push injection equipment. Colloidal amendments, with a particle size of about one micrometer, are an emerging class of engineered remediation materials that can overcome injection and distribution problems associated with larger particle size materials. When blended with EVO and other organic amendments a low-viscosity, hydrophilic injectate with particles and droplets that are small enough to fit within and pass through the interconnected porosity of many soils can be produced. This mixture allows for using relatively low-pressure injections that promote a more uniform distribution of the remediation amendments. We present the results of a remediation program at Niagara Falls ARS where a colloidal iron product, an EVO product, and an anaerobic bacteria consortium containing dehalorespirers were mixed and diluted in water.

**Approach/Activities.** Mixing was accomplished by adding municipal water to a dual batch mixing system with 350-gallon tanks into which colloidal iron and EVO suspensions were added. This hydrophilic mixture was water-like and colloidal stability could be maintained with gentle recirculation and agitation. The suspension was injected into a grid of temporary injection points using a 12 to 15 ft well spacing. Direct push borings were drilled with 1.5-inch retractable stainless-steel injection screen (3 ft) or 1.5-inch expendable points. Microbes were metered into the injection hoses downstream of the mixing tank near the injection points. The mixture was injected into fractured, clay dominant glacial overburden and weathered, calcareous bedrock at low pressures into groundwater containing TCE and daughter products at four sites at Niagara Falls ARS. Over the course of the 10-day injection program a total of 19,000 gallons of injectate was applied into 54 injection points across four sites.

**Results/Lessons Learned.** Using a low viscosity injectate with small particles and droplets allowed for the product mixture to be injected at wellhead pressures averaging typically less than 20 psi with a flowrate of about 2 gpm. Low injection pressures and stable flow rates resulted in limited daylighting even when product was applied into shallow injection points and resulted in a better than anticipated injection ROI with good vertical distribution of injectate into secondary porosity pathways in the fractured, clay overburden. Increases in water levels in both overburden and shallow bedrock monitoring wells within, and adjacent to, the injection grid were observed during the injection process, indicating successful distribution to interconnected fractures in the both clay and underlying bedrock. Monitoring results indicated a near-immediate change in geochemical parameters decreasing ORP to -200 mv or lower in most wells, and the first round of sampling indicated a rapid decrease in concentrations of both parent and daughter products at most monitoring wells within each treatment area.