# Hydraulic Emplacement of Zero-Valent Iron Coupled with In Situ Bioremediation for VOC Treatment in a Low-Permeability Aquifer

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**Background/Objectives.** Historical releases of tetrachloroethene and trichloroethene at an active aircraft parts manufacturing facility in central Kansas produced two distinct dissolved volatile organic compound (VOC) groundwater plumes in a shallow low-permeability overburden aquifer. Analytical data from decades of groundwater sampling were evaluated to show that the plumes were stable, and migration of the dissolved VOCs is controlled by intrinsic reductive dechlorination and non-transformative attenuation mechanisms at the plume margin. Over the last two years, a plan to remediate the plumes via a combined chemical reduction with zero-valent iron (ZVI) and in situ bioremediation (ISB) was developed and implemented.

**Approach/Activities.** The remedy involved source treatment with a two-step process starting with hydraulic emplacement of ZVI to create stacked subsurface propagations of higher permeability relative to the silty clay overburden soils, followed by the installation of injection wells interconnected to these features through which ISB amendments were deployed. The use of these enhanced injection wells was critical to the efficient injection and thorough distribution of ISB amendments in a tight clay formation. The injection locations were bioaugmented with KB-1® during both stages of the remedy. The study presents the procedures of hydraulic emplacement of the ZVI propagations and presents novel methods to install injection wells through them using direct-push technology. The goal of this remedial approach was to leverage the optimization of the groundwater geochemistry through chemical reduction with ZVI to enhance the survival and growth of the KB-1® and increase treatment area permeability for ISB amendment distribution. We show how this approach can be used to treat chlorinated solvent source areas in challenging low permeability settings.

**Results/Lessons Learned.** Results of this study demonstrate that the novel injection design resulted in higher injection efficiency and subsurface amendment distribution. Using multiple performance monitoring metrics (i.e., geochemical parameters, VOCs, isotopes, and molecular testing), post-treatment groundwater sampling results after ZVI and ISB injections show significant VOC dechlorination in the source area, resulting in an overall decrease in VOC plume area. Isotopic enrichment of daughter VOCs conclusively indicates that accelerated reductive dechlorination is the mechanism responsible for the decreasing VOCs in the source areas wells. The quantitative polymerase chain reaction results show the survival and growth of dechlorinating microorganism populations in source area wells.