

# Lessons Learned: In-Situ Bioremediation in a Heterogeneous Aquifer Using Recirculation Wells Inside Hydraulic Containment

**Patrick Hsieh** (phsieh@dofnw.com) and Tasya Gray (ngray@dofnw.com)  
(Dalton, Olmsted, & Fuglevand, Inc., Seattle, WA, USA)

**Background/Objectives.** The goal is active in situ bioremediation (ISB) of a plume of chlorinated VOCs (25 to 40 feet bgs) with suspected DNAPL at approximately 60 feet bgs in a heterogeneous aquifer in south Seattle, Washington. The target aquifer consists of discontinuous interbedded fine sand, silty sand, and sandy silt lenses. A subsurface slurry barrier wall was installed around the plume in 2004 and tied into a silt aquitard approximately 60 feet below ground surface. Approximately 3 acres are entirely contained (no natural groundwater flow through the ISB target area). A 5 gpm pump and treat system is sufficient to maintain a 1-foot hydraulic gradient working in unison with the barrier wall and surface capping.

Treatment of chlorinated VOCs by ISB is a mature remedial measure, however, this site has a heterogeneous aquifer, flow barriers due to hydraulic containment, high iron content in the aquifer, and a microsilica concrete cap covering 65% of the treatment area. Conditions led to system design that includes multiple configurations and flexibility in setup in order to allow operators to adjust treatment approaches as field conditions show changes from design assumptions (or as fouling occurs over time). The presence of DNAPL at depth further complicated negotiations with regulators on remedial goals and feasible dosing appropriate for the site.

**Approach/Activities.** The ISB system consists of six extraction wells, 42 injection wells, and a portable injection cart with hoses to connect various recirculation cell configurations. Initial injections of high fructose corn syrup began in 2016 and four rounds of injections have been performed through August 2018. Groundwater monitoring is performed immediately before and after each injection, with additional monitoring performed in-between injection rounds to assess if target substrate concentrations should be adjusted.

Monitoring includes field parameters (groundwater- dissolved oxygen, redox potential, conductivity, turbidity, and temperature as well as vapors-oxygen, methane, VOCs) and laboratory analysis of groundwater for total organic carbon, methane, nitrate/nitrite, alkalinity, sulfate/sulfide, ferrous/ferric iron, and VOCs. Demonstrating effective substrate distribution was a primary goal of system operation monitoring.

**Results/Lessons Learned.** The ISB injection system has created appropriate conditions to support anaerobic bioremediation of chlorinated VOCs. However, the injection system setup and operations has been modified to adjust to changing aquifer conditions and regulatory requirements. Methods initially required to demonstrate effective substrate distribution led to biofouling. Limits in accuracy for real time testing methods for TOC and required dosing levels led to inefficient operations that necessitated working with regulators through several alternative methods to demonstrate effective distribution of substrate. After the first round of injections sufficient data was available to demonstrate to the regulator that the higher concentration of substrate dosing proposed was not feasible given site conditions.

To address biofouling, the dose of substrate and injection timing was altered to limit the concentration of substrate reaching extraction wells. Additional details on system optimization, regulatory hurdles, substrate management, and cost optimization techniques will be presented.