

## **A Comparative Study of the Ability of ISCO and EISB to Treat Multiple Contaminants at a Complex Industrial Landfill Site**

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**Background/Objectives.** The site of interest is a large industrial landfill in the northeastern United States. Mobile contaminants in the landfill include chlorinated ethenes (trichloroethene and daughter products), BTEX compounds (primary benzene and toluene), chlorobenzene (CB) and 1,4-dioxane (1,4-D). The geology is complex, with a thick (minimum 2 meters) clay cap overlaying natural deposits of permeable sand and silt intermixed with less permeable layers of silty clay, underlain by a glacial till and fractured bedrock. The objective of this study was to evaluate certain in-situ technologies capable of addressing the contaminant mix in the groundwater below the capped area as part of a feasibility study.

**Approach/Activities.** A laboratory treatability study was performed to evaluate the efficacy of both in situ chemical oxidation (ISCO) and enhanced in situ bioremediation remedial (EISB) approaches. The ISCO approach utilized base or iron activated persulfate, while the EISB approach utilized a number of amendments, including lactate, EVO, EHC™ and sulfate. In the case of EISB, some bottles were bioaugmented with commercial cultures capable of degrading both chlorinated ethenes and BTEX compounds. ISCO and EISB treatments were evaluated separately, but sequential treatment (ISCO followed by EISB) was also explored. In all cases, the soil and groundwater samples used in the microcosm bottles were collected from both the permeable (Location 1) and less permeable (Location 2) areas under the clay cap. Microcosm bottles were also included for sterile and intrinsic controls.

**Results/Lessons Learned.** The results of the ISCO treatment were straight-forward. Both activated forms of persulfate degraded all the contaminants in 28 days at persulfate loading rates varying from 20 to 60 g/L. However, base-activated persulfate was faster than iron-activated persulfate. The degradation rate differential was most apparent for 1,4-dioxane. A subset of the bottles were then quenched, neutralized, respiked with contaminants, and lactate was added to promote biological activity. These bottles were also bioaugmented. Biodegradation activity was subsequently noted, particularly in the location 2 bottles.

As expected, results of the EISB treatments were more complex because the contaminant mix requires multiple sets of bacteria and is degraded via multiple degradation pathways. Of significant note was the complete removal in 120 days of all the chlorinated ethenes, BTEX compounds, and CB in the intrinsic control in duplicate Location 1 bottles. This result is highly unusual in our experience. Removal of all the chlorinated ethenes, BTEX compounds, and CB was also observed in some of the amended and bioaugmented bottles. While all carbon amendments enhanced the reductive dechlorination of the chlorinated ethenes, slow-release donors such as EVO or EHC™ inhibited the degradation of BTEX and CB. Biodegradation activity was more extensive in bottles containing Location 1 soils. Consistent with the literature, no biodegradation of 1,4-D was observed in any of the EISB studies.

Given the highly unusual performance of the intrinsic controls, several samples were sent to the University of Toronto at the conclusion of the study for microbial community analysis using next generation sequencing (NGS). Preliminary evaluation of the NGS results suggest that known dechlorinating bacteria such as *Dehalococcoides* and *Geobacteraceae* were among the 20 most abundant amplicon sequence variants in these samples, as well as a *Desulfosporosinus* (a putative toluene degrader).