Pilot Testing of In Situ Chemical Reduction-Enhanced Bioremediation at a Former Manufacturing Plant in Germany

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Background/Objectives. Chlorinated hydrocarbons (CHCs), mostly tetrachloroethylene, were detected in groundwater beneath a former manufacturing plant (Site) in west-central Germany. Recent remediation efforts at the Site have included implementation of a recirculatory enhanced reductive dechlorination (ERD) system for treatment of CHC in the sand and gravel formation. Review of recent groundwater data indicated that the recirculatory ERD system, as currently configured, may be approaching an asymptote. A transition to direct injection of ERD amendments, or similar, was recommended to more effectively target and treat the highest remaining dissolved CHCs near the eastern property boundary.

Approach/Activities. A pilot test of in situ chemical reduction (ISCR)-enhanced bioremediation was conducted at the Site to assess its effectiveness on reduction of CHCs in an underlying sand/gravel layer. A commercial ISCR reagent (EHC®), consisting of zero valent iron (ZVI) and a slow-release organic carbon source, was applied along with KB-1®, a mixed consortium of anaerobic dechlorinating bacteria for bioaugmentation, to intercept and mitigate CHCs in groundwater near the Site boundary. Approximately 1,900 kg of EHC® and 13.5 L of KB-1® were successfully injected at three injection points over a five-day period via conventional direction push technology (DPT) into a target area from 9 to 13.5 meters below ground surface (m bgs). Three sand and gravel monitoring wells located approximately 2.7 to 4 m downgradient from the pilot study injection points were sampled quarterly to evaluate treatment performance.

Results/Lessons Learned. Visual observations, field magnetic susceptibility measurements and iron content laboratory analyses from core samples collected after injections provided multiple lines of evidence that ZVI was successfully emplaced in the sand/gravel layer. ZVI was injected with an observed radius of at least 1.3 m in the sand/gravel layer. Reducing conditions were enhanced in the sand/gravel layer within one month of ZVI injection, as evidenced by (i) reduced oxidation-reduction potential (ORP) (i.e., more negative) and (ii) a gradual increase of dissolved iron gradually seven months after injection. CHC concentrations initially increased during the first month of post-injection monitoring, likely due to promoted solubilization of CHC from the aquifer matrix by the injected amendments, and subsequently decreased at two downgradient monitoring wells within four months. Ethene and/or ethane increased during this time period as well, indicating active dechlorination. Molecular analyses (Gene-Trac) for *Dehalococcoides* and *vcrA* (a gene found in *Dehalococcoides* bacteria that are capable of metabolically dechlorinating cis-dichloroethylene and Vinyl chloride to ethene) in groundwater confirmed successful development of moderate concentrations of *Dehalococcoides* and *vcrA* within seven months after bioaugmentation. The decrease of CHC concentrations in groundwater observed at the Site can be attributed to both abiotic and biotic mechanisms.