Innovative ZVI Application for Sustainable Remediation of Chlorinated Solvent Plumes

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Background/Objectives. There is a large demand for sustainable remediation techniques to ensure clean water as also indicated by UN's goal no. 6. The objective of this project is to thoroughly test and document a method that can be used at contaminated sites all over the world.

Approach/Activities. Pre-design microcosm and column test reactors with five different ZVI-products were prepared using site groundwater and aquifer materials to identify the optimal ZVI-product for a pilot scale permeable reactive barrier (PRB). Provect-IR® and bioaugmentation with KB-1® culture achieved the most complete treatment in the bench test and was selected for the pilot test at a cVOC site. Provect-IR® contains a natural anti-methanogen compound to inhibit methane production, which can be problematic in urban areas.

Three different methods were tested to identify the most effective method for injecting the ZVI-carbon and KB-1® culture. DPT with a Geoprobe rig showed the best injection effectivity. Subsequently, a pilot scale PRB was installed through 7 DPT injection points arranged in 2 rows of off-center points at the site. The Provect-IR® design dose was 1% by weight of soil and KB-1® dechlorinating culture (4 L per injection point) was added. Installation of the PRB was followed by a detailed documentation of the distribution of ZVI by means of soil core sampling and analyses (magnetic susceptibility, visible iron, and laboratory iron analysis) and comprehensive depth specific water sampling.

To allow PRB performance monitoring, three transects of monitoring wells were installed. Baseline monitoring confirmed expected iron reducing conditions, significant concentrations of TCE and cDCE, and minor concentrations of VC. Only trace concentrations of ethene and ethane were observed, showing a lack of complete degradation. The performance monitoring program including chemical as well as microbial analysis and Compound Specific Isotope Analysis (CSIA) to document and quantify biotic and abiotic degradation has included quarterly groundwater sampling to establish cVOC degradation trends and calculate cVOC mass/flux removal in the plume. Final monitoring and documentation was performed in October 2022.

Results/Lesson Learned. Complete degradation of cVOCs to ethene/ethane was observed in areas with sufficient distribution of Provect-IR® and KB-1® culture. The degradation was predominantly caused by the injected Provect-IR® and KB-1® culture, since only 8% decrease was observed to occur naturally. In areas where the distribution was less successful, also less degradation was observed.

Dual isotope plots indicated that degradation pathways changed from solely biotic to a combination of biotic and abiotic degradation after creation of the PRB. Only minor methane production was observed in the groundwater, and it seems that the methane inhibitor in the product was sufficient to avoid critical methane spreading in the area.

The remediation is done in a sustainable way, and where sufficient distribution of Provect-IR® and KB-1® culture is obtained, the remediation is very promising. Furthermore, the method will be applicable to contaminated sites all over the world.