Denmark's First Full-Scale Microscale Zero Valent Iron PRB Emplaced by Direct Push Injection

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Background/Objectives. Due to several unsuccessful zero valent iron (ZVI) permeable reactive barrier (PRB) remediation projects in Denmark during the 1990s, ZVI PRB technology has not been used for many years in Denmark and until recently has not been considered a mature or cost-effective technology. Based on the growing number of ZVI PRBs case examples in North America, the first full-scale micro scale ZVI (mZVI) PRB emplaced with direct push technology (DPT) was installed in Denmark in 2016. The PRB was installed to treat a cis-1,2-dichloroethene (cDCE) and vinyl chloride (VC) plume in thin sand aquifer (12 – 14 mbs) occurring underneath a low-permeability (clay till) source area at a former industrial site. The project was challenged by high influent concentrations of VC (up to 13,000 µg/L) and cDCE (up to 12,850 µg/L) and a treatment requirement for a 99% reduction in cDCE and VC.

Approach/Activities. For reasons of the specific contamination with cDCE and VC, detailed preliminary hydrogeologic and contaminant distribution investigations, laboratory treatability testing, and injection testing were carried out before completing design of the full-scale PRB. In the laboratory tests, four types of iron were tested in order to choose the most efficient type of ZVI for treating cDCE and VC in site groundwater. Injection tests were performed in order to assess the mixture of mZVI, radius of influence (ROI), and injection pressure under site-specific conditions. Because of heterogeneous geology, a detailed mapping of the vertical contaminant distribution in the target treatment was performed using a membrane interface/Hydraulic profiling tool (MiHpt/Hpt), prior to installing the PRB. The full-scale PRB was installed via 210 DPT injection points. The mZVI material was suspended in a guar gum, which was used to create a pumpable ZVI slurry. A total of 12 tons mZVI and 240 kg guar were injected. Because of the potential for the added guar to cause biological dechlorination to increase VC concentrations, dechlorinating bacteria (KB1) were included in the injectate to enhance biotic dechlorination. The injections were carried out in October/November 2016. Injections were performed both below the source area to prevent vertical spreading and downstream the source area to prevent horizontal spreading.

Results/Lessons Learned. The extensive preliminary investigations and the laboratory and pilot tests have been indispensable. The laboratory tests showed a major difference in the efficiency of the four tested ZVI types towards especially breakdown of VC, and that VC is the most critical compound to treat with a half-life of 25 hours. The injection tests gave important information on injection methods and requisite spacing of the injection points. The preliminary detailed mapping of the injection area with MiHpt/Hpt turned out to be a very useful tool for a targeted and accurate placing in the injection area and avoided expensive waste of time. The monitoring results from the first year show excellent results in which the clean-up criteria were achieved downstream of the PRB. Compared to other groundwater remediation techniques, an mZVI PRB installed via DPT is assessed to be robust and cost effective, and could advantageously be used on other similar projects in Denmark. A challenge in assessing the results is the difficulty in distinguishing between biotic dechlorination (due to KB1 and guar fermentation) and abiotic dechlorination (due to ZVI). Another challenge is the uncertainty

regarding the reactive longevity of the PRB. In this project, the longevity has been assessed to be in the interval 5-10 years, but this is still uncertain.