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Bioremediation Integrated Approach for Chlorinated Compounds in a Complex Brazil Facility

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Background/Objectives. The application of enhanced anaerobic dechlorination (EAD) to bioremediate groundwater impacted with chlorinated volatile organic compounds (CVOCs) at an active manufacturing facility near São Paulo posed challenges with respect to hydrogeology, low aquifer pH, contaminant distribution, low permeability soil, on-site/off-site access, cost of amendment and uncertainties related to the conceptual site model. An Intervention Plan was prepared in late 2011 and remediation activities started in 2012, using bioremediation techniques to provide required subsurface conditions that support anaerobic dechlorination processes. New information provided by site assessment activities conducted in parallel with the remediation, and confirmation of historical contaminant sources in areas of relatively low permeability, led to modifications to the initial remedial approach, aiming not to exceed the overall desired timeframe of groundwater remediation of the site. From 2012 to 2016, three different reductive approaches have been used, in response to the challenges related to specific subsurface and property use conditions within the site vicinity.

Approach/Activities. Based on technical feasibility, cost, and implementability criteria, active groundwater remediation using EAD technology was implemented. The electron donor (sodium lactate) has primarily been injected using groundwater re-circulation as opposed to batch injection. A Phase 1 EAD system consisted of eight injection and extraction and 10 batch injection wells (off site), and commenced operations in 2012. A Phase 2 EAD system consisted of 30 injection and extraction wells (onsite), and commenced operations in 2013. From 2012 to 2015, a total of almost 150,000 L of amendment was injected in the subsurface and almost 27,400 m^3 of groundwater was re-circulated with the EAD system. Based on a recently-identified third plume of impacted groundwater, an additional biotic as well as abiotic reductive approach was designed and implemented. This additional reductive approach is based on the use of zero valent iron (ZVI) and carbon amendment electron donor. Direct push techniques were used for these additional injections, whose took place between late 2015 and early 2016. A total of almost 24 metric tons of amendment solution was injected during both phases of ZVI and carbon amendment injection.

Results/Lessons Learned. Considering the two initially-identified plumes of impacted groundwater, after 3 years of the operation of the EAD remediation system, the impacted area decreased from 40,000 m^2 to 16,000 m^2. The average PCE concentration within the identified impacted groundwater decreased from 3,200 ug/L to 2,100 ug/L within the same timeframe. The results of the late 2015 Phase 1 direct push injections of ZVI and carbon amendment showed a significant reduction in PCE concentration (17.5 mg/L to 0.8 mg/L) after 30 days from the injection. Phase 2 direct push injections of ZVI and carbon amendment designed to act in another critical area is ongoing and should be completed during 2016. Low permeability soils, low aquifer pH and high concentrations of PCE in portions of the site adversely affected EAD System performance. Zero valent iron and carbon amendment electron donor to enhance chemical and biological reductions was applied through direct push injections to address these challenges. Direct push injection under relatively high pressure has facilitated amendment distribution within the low permeability soils. Hydroxyl ions produced from corrosion of ZVI may

have contributed to a measured increase in aquifer pH values, which are supportive of *Dehalococcoides* microbial development needed for complete dechlorination.