Monitoring the Impacts and Effectiveness of Electrical Resistance Heating Combined with Enhanced Bioremediation

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Background/Objectives. Electrical resistance heating (ERH) is an aggressive and now well-established in situ thermal remediation (ISTR) technology for contaminant mass removal, particularly in source areas with residual dense non-aqueous phase liquids (DNAPL). During traditional applications of ERH, temperatures of 100°C are reached driving volatilization, enhanced evaporation, and steam entrainment of contaminants which are captured through soil vapor extraction (SVE). While these high temperatures would seemingly limit biodegradation, recent evidence suggests that more moderate heating (i.e. 35-50°C) not only accelerates dissolution/desorption but also may enhance abiotic and biotic degradation. In the current study, QuantArray was performed along with traditional groundwater monitoring to evaluate the impact of ERH operations on concentrations of halorespiring and petroleum hydrocarbon utilizing bacteria within and adjacent to the source treatment zone.

Approach/Activities. The study site is a former dry cleaning facility impacted by tetrachlorethene (PCE), trichloroethene (TCE), chlorinated solvent daughter products, and petroleum hydrocarbons (Stoddard Solvent). A total of 15 electrodes were installed within a 1,600-ft^2 area to depths of 45 feet below ground surface (BGS). During 8-months of sustained ERH operations, groundwater samples were obtained periodically for VOCs analysis and QuantArray quantification of halorespiring bacteria (e.g., *Dehalococcoides*) and functional genes (e.g., vinyl chloride reductase, benzylsuccinate synthase). Upon system shutdown, confirmatory sampling was conducted to evaluate contaminant mass removal.

Results/Lessons Learned. Overall, ERH was very effective in reducing contaminant mass within the source area. Soil PCE concentrations decreased from as high as 170 mg/kg to less than 0.02 mg/kg in all post-ERH soil samples while groundwater PCE, TCE and cis-1,2-DCE concentrations decreased by one to two orders of magnitude. The ERH system operated under a contaminant mass reduction approach, reaching average temperatures of 80-90°C and sustained temperatures over 100°C at targeted depth intervals. However, the subsurface temperature increase occurred over a period of 1.5 months and temperatures at some intermediate depths (35-45 feet BGS) remained more moderate (40-60°C) throughout system operation. Prior to ERH, total bacteria concentrations were on the order of 10^6 cells/mL and populations of *Dehalococcoides* were moderate (10^2 to 10^3 cells/mL). After temperatures increased to the 50-60°C range, *Dehalococcoides* populations decreased substantially but concentrations of other halorespiring bacteria including *Dehalobacter* spp. did not appreciably decrease. At shallower depths (FMW-3), temperatures increased to between 70 and 100°C during the bulk of system operations and microbial populations continued to decline. For the intermediate depth interval (FMW-24), where temperatures remained less than 60°C, microbial populations also decreased but halorespiring bacteria were still detected even after 8 months of ERH. While volatilization was the treatment mechanism in the current study, the maintenance of halorespiring and BTEX-degrading microbial populations has important and encouraging implications for implementing thermally enhanced bioremediation following an ERH treatment, concurrent biodegradation in adjacent areas during ERH operation, and for biodegradation during moderate temperature ERH operations.