Heated Water Recirculation to Enhance In Situ Abiotic and Biotic Degradation

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Background/Objectives. This presentation will present the theoretical basis for heat enhancement of biological degradation and provide examples and lessons learned from a Formerly Used Defense Site (FUDS) trichloroethene (TCE) site in Nebraska where this approach was implemented. Biodegradation of environmental contaminants in groundwater is a common component of remedies for both active and passive processes. For chlorinated solvents these processes can include reductive dechlorination and in some cases oxidation. Additionally, microbially-mediated geochemical changes may result in geochemical conditions that allow formation of minerals that react with solvents by abiotic processes. Biological processes that occur in the subsurface have been shown to occur at faster rates when temperatures are higher. Therefore, increasing subsurface temperatures has the potential to increase biodegradation rates and thereby reduce treatment timeframes. Recirculation of groundwater that is heated prior to re-injection offers an efficient means of heating to achieve these benefits.

Approach/Activities. Several optimization approaches were designed and implemented to facilitate enhancement of natural attenuation of TCE at this site. Design included modeling using the USGS model VS2DH for heating, comparing a static electrode at the groundwater surface against injection of heated water. Groundwater capture was evaluated using the USEPA model WhAEM by modifying injection and extraction well locations and flow rates to focus heating and recirculation on areas with TCE impacts. The optimization approach consisted of three heated water injection wells, two extraction wells, and four nested in situ enhanced bioremediation injection wells. These were plumbed to an equipment shed that included solids filtration, heaters and granular activated carbon treatment vessels. Heated groundwater recirculation coupled with ISEB amendment injection was focused on the source area during the first phase of work, and then transitioned to the downgradient plume. The process has been monitored with groundwater sampling for target compounds, methane-ethene-ethane (MEE), total organic carbon, microbial communities with qPCR and next gen sequencing. Subsurface temperatures have been measured with transducers and depth-discrete measurements with a field meter. In situ microcosms were deployed and parallel laboratory bench tests were performed as well.

Results/Lessons Learned. Recirculation of heated groundwater has been effective at increasing the subsurface temperature. During the first phase of treatment water was injected at temperatures of up to 115°F (46°C). Subsurface temperatures in a monitoring well in the treatment zone increased from 56°F (13°C) to 88°F (31°C) while the temperature of extracted groundwater increased to 68°F (20°C). TCE concentrations have been reduced by over 90% within the footprint of recirculation. Evidence suggests that abiotic and biotic degradation processes may have been involved, though physical flushing likely played a role. Bacterial populations increased in the area where heat and ISEB amendment were applied. In the parallel laboratory study, TCE degradation, sulfate reduction, methane production, and depletion of volatile fatty acids (VFAs) all occurred at more rapid rates at 115°F (27°C) versus comparable reactors maintained at 56°F (12°C).