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The Influence of Complex Fractured Bedrock on In Situ Enhanced Reductive Dechlorination of TCE

Frank Barranco (fbarranco@eaest.com), Kathy Fox, and Jesse Drummond (EA Engineering, Science, and Technology, Inc., PBC, Abingdon, MD, USA)
Bruce Rundell and Ryan Bower (USEPA, Philadelphia, PA, USA)

Background/Objectives. Unapproved waste disposal at a former landfill site in Northern Virginia resulted in a dilute, approximately 207 acre TCE plume that extends to a depth of 500 ft in fractured bedrock. Maximum observed TCE concentrations are 500 ppb. The Site is located in the Triassic-age Culpeper Rift Basin (red siltstones). Hydrogeologic conditions are dominated by fracture flow through a complex network of low-angle bedding-plane partings and higher-angle fracture joint sets. Primary porosity is characterized as low and likely contributes to slow-matrix diffusion of TCE. Treatment was designed to: 1) evaluate the effectiveness of distributing bioremediation amendments, 2) assess the breakdown of TCE through in situ biological and chemical reduction, and 3) determine the relative influence of bedding plane partings versus fracture joint sets on reagent delivery and treatment footprint.

Approach/Activities. Treatment was conducted using a long-lasting chemical reductant (EHC®-Liquid[EHC®-L] and a dechlorinating microbial culture (SDC-9™) to enhance biological reductive dechlorination and chemical reduction. Approximately 40,000 gallons of aerobic groundwater was extracted from an injection well, placed in mixing tanks, and converted to anaerobic conditions with sodium lactate. SDC-9™ was added to the mixing tanks once anaerobic conditions were established. Approximately 6,720 pounds of 25% EHC®-L was batch mixed with the supply of anaerobic groundwater to obtain a 0.5% solution of EHC®-L per injection interval. Inflatable straddle packers were installed within 20-ft zones of 13 vertically discrete intervals (182-460 ft) within the treatment zone. Specific injection volumes per interval were calculated based on the fracture density observed on the geophysical logs. The average injection flow rate was 43 gpm at an average pressure of 10 psi. Monitoring well cluster locations were placed 150 ft from the injection well along bedding plane strike and 75 ft from the injection well along the primary direction of the strike of the fracture joint sets. Each cluster location contained a 250 ft and 500 ft well. Each well was constructed with three sealed and individually screened water bearing zones.

Results/Lessons Learned. Targeted open bedding planes and fracture sets, as expected, accepted the largest volume of amendment. Pressure transducer responses indicated that there was a variable degree of connectivity between the injection intervals and the monitoring wells. The establishment of reducing conditions in monitoring wells located down-dip along bedding plane partings was observed within 3 days of injection. Conversely, establishment of reducing conditions took longer (by factor of 10) for monitoring wells located along strike (or dip) of observed fracture joint sets. These results provide meaningful data concerning the mechanisms related to transmitting amendments to targeted locations in the treatment area. Bedding plane partings appear to provide the shortest flow path for delivery. Radius of influence was significantly greater than expected; presumably, as a result of directional flow within linearly oriented bedding plane partings and fracture joint sets. Post-treatment monitoring indicators of the dechlorinating microbial culture show that longer-than-expected timeframes (approximately one year) are required to establish a healthy and viable microbial population in fractured rock at this Site. This finding is presumably related to the limited degree of surface area for establishment of a stationary microbial population.