CSM UPDATE AND EXPANSION TO SUPPORT IN SITU BIOREMEDIATION OF CVOCS IN IMPACTED OVERBURDEN AND METAMORPHIC BEDROCK GROUNDWATER

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Background/ Objectives:

A hydrogeologic investigation was completed to update a conceptual site model (CSM) for a site in the northeast United States with zchlorinated volatile organic compound (CVOC) impacts. The site is located adjacent to surface water, with a complex geologic setting, including weathered and fractured bedrock. Bedrock at the site is a gneissic rock with hard to predict fracture patterns, low porosity, and crystal structure. Groundwater flow in the surficial aquifer is generally towards a dammed lake. Challenges in characterizing bedrock migration potential and risk to receptors were identified and became the basis for collecting additional bedrock details and updating the CSM prior to pilot testing. Properly designed pilot tests can provide means of collecting new soil, bedrock, and contaminant characterization detail which can then support further site knowledge prior to remedial action. This investigation was completed in three steps: an initial hydrogeological characterization, the development of a revised CSM, and application of the pilot-scale enhanced in situ bioremediation (EISB).

Approach/Activities:

Bedrock characterization tests were conducted to assess the potential of bedrock migration pathways, particularly deeper than 45 feet where conflicting information existed. The conflict consisted of bedrock liner sampling that indicated CVOC impacts were present at depth, however no migration pathways could be identified. Discrete bedrock fracture strike and dip measurements were previously collected from downhole geophysical instrumentation. These measurements were included in a discrete fracture analysis as part of the updated CSM to support where CVOC impacts to groundwater may exist. Subsequently, borefluid replacement testing (a type of in-well tracer test) was conducted to evaluate the source of potentially deep CVOCs in the gneissic bedrock. Based on the results of the borefluid replacement testing the CSM was further revised to support the implementation of the pilot-scale EISB.

Based on the evaluation of historical data, borefluid replacement and slug testing, an EISB pilot test was designed. The pilot test primary objectives were to: 1) determine the extent of source area CVOCs in real time (during drilling) with a CVOC field analysis kit; 2) determine the horizontal radius of influence and injectability of the EISB substrate in real time using Bluetooth-enabled pressure and specific conductance probes; 3) protect the surface water from injectate (electrolytes and organic energy source to support microbes) daylighting; 4) determine the downgradient flow potential and substrate effectiveness after injections; and 5) evaluate the extent of connectivity of weathered and fractured bedrock within the site area.

Results/Lessons Learned:

The borefluid test confirmed shallow (35-45 feet below ground surface) transmissive bedrock fractures as identified in prior borehole geophysical assessments, and determined that the deep bedrock CVOC impacts were likely “carry down” during bedrock liner testing. This finding allowed for an update to the CSM and design of the in situ bioremediation to target the surficial aquifer (overburden and partially weathered rock) where the highest concentrations were present.
Field monitoring techniques established multiple lines of evidence of injectate transport throughout

the pilot test area in the surficial aquifer during injections. Field screening techniques allowed to further delineate the extent of CVOCs and guided the placement of injection and monitoring wells. Although highly variable due to heterogeneity, the radius of influence was 10 to 15 feet. Detections of the non-reactive fluorescein salt tracer were limited outside of the pilot test injection area, indicating limited and/or low flow conditions to areas cross or upgradient of the injection area. Subsequent EISB performance monitoring has identified strong evidence of full biodegradation to ethene at locations within the injection zone, supported by trends in CVOCs, microbial populations, total organic carbon, and other geochemical conditions. The success of injections extended beyond the injection area, and monitoring wells downgradient of the injection area also have shown multiple lines of evidence of EISB influence. Results (to date) were inconclusive with respect to connectivity between the surficial aquifer injections and the discrete bedrock fractures.

Several lessons learned were identified from the pilot test as the site progresses towards full-scale implementation, including areas where additional treatment is needed and the consideration of alternative substrate application methods. The CSM refinement throughout the pre- and post-pilot implementation have informed the understanding that CVOCs in bedrock fractures are of low risk and therefore may be a candidate for monitored natural attenuation.

About The Author

Hannah is a senior geologist specializing in contaminant fate and transport. She has seven years of experience including laboratory research on fate and transport mechanisms for chlorinated volatile organic compounds (CVOCs) and per- and polyfluoroalkyl substances (PFAS), and environmental investigations and remediation for industrial clients.