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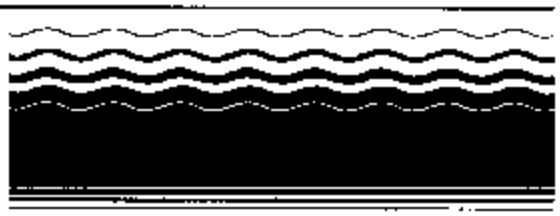

Demonstration Bulletin

Enhanced In-Situ Bioremediation Process

Earth Tech, Inc.

Project Description: The U.S. Environmental Protection Agency (EPA) conducted an evaluation of the Enhanced In-Situ Bioremediation Process, a biostimulation technology developed by the U.S. Department of Energy (DOE) at the Westinghouse Savannah River Plant site in Aiken, South Carolina. DOE has licensed the process to Earth Tech, Inc. (Earth Tech). The evaluation described in this bulletin was carried out by the EPA Superfund Innovative Technology Evaluation (SITE) Program. Earth Tech is utilizing the process to deliver a mixture of air and gaseous phase nutrients, and/or methane to contaminated groundwater in fractured bedrock at a site in Roanoke, VA. These enhancements are delivered to contaminated groundwater via an injection well and were designed to stimulate and accelerate the growth of existing microbial populations, especially methanotrophs. This type of aerobic bacterium has the ability to metabolize methane and produce enzymes capable of degrading chlorinated solvents and their degradation products to non-hazardous constituents.

The primary components of Earth Tech's treatment system consist of an injection well, air injection equipment, groundwater monitoring wells, and soil vapor monitoring points. The injection well is designed to deliver air, nutrients, and methane to groundwater in the bedrock 30 to 50 feet below ground surface. For the system evaluated, the air was supplied by a compressor that was capable of delivering 15-30 psi and approximately 20 scfm to the injection well. The monitoring wells and soil vapor monitoring points were installed upgradient, down-gradient and cross-gradient relative to the injection well location to delineate the zone of influence and to monitor groundwater within and outside of the zone of influence. The soil vapor monitoring points can be designed to release or capture vapors that may build up in the overburden. The monitoring wells were constructed in a manner to allow them to be converted to either injection wells or soil vapor extraction points.

The typical injection system consists of air, nutrient, and methane injection equipment; all can be housed in a temporary building or shed. A compressor serves as the air source, and includes a condensate tank ("trap") with a drain, an air line, coalescing filters and pressure regulators and valves. The methane and nitrous oxide provide the source of carbon and nitrogen, respectively. Both are provided in standard gas cylinders and are piped into the main air line using regulators and flow meters. Triethyl phosphate (TEP), the phosphorous source, is in liquid state and is stored in a pressure rated steel tank. Air from the main line is diverted through the tank to volatilize the TEP for subsurface delivery. The air, nitrous oxide, and TEP are injected continuously while the methane is injected on a pulsed schedule. The methane is closely monitored just prior to injecting into subsurface wells to ensure that the injection concentration does not exceed 4% by volume, thus avoiding the methane lower explosive limit (LEL) of 5%.

Waste Applicability: The Enhanced In-Situ Bioremediation process is applicable for treating volatile organic compounds (VOCs) in groundwater that can be naturally biodegraded, including some hard to degrade chlorinated VOCs. The mixture of air and gaseous phase nutrients that is injected into the subsurface provides an aerobic environment for contaminant degradation. Toxic products resulting from anaerobic degradation of chlorinated solvents (e.g., vinyl chloride) may be broken down completely in this aerobic environment. The in-situ process is especially applicable for hydrogeologically complex sites where injected nutrient flow paths are uncertain (i.e., in fractured bedrock gaseous phase nutrient injection is more likely to affect a larger area than liquid nutrient injection). The process is also applicable in situations where subsurface utilities limit or preclude the use of technologies requiring excavation.

Demonstration Results: A pilot-scale technology demonstration of the Enhanced In-Situ Bioremediation process was conducted from March 1998 to July 1999 at the ITT Industries Night Vision (ITTNV) Division plant in Roanoke, Virginia. The ITTNV facility is an active manufacturing plant that produces night vision devices and related night vision products for both government and commercial customers. Groundwater contamination at the facility has resulted from tank leaks of both chlorinated and non-chlorinated compounds, which were used as manufacturing cleaning solvents. Remediation is being conducted at the facility as a RCRA Interim Measure (IM), and is complicated by target VOCs occurring in fractured bedrock

below the surface. This logistical complexity presented by the area geology was a key factor for selecting the Enhanced In-Situ Bioremediation process.

The demonstration study area was located adjacent to ITTNV's commercial operations building (Building 3), and was immediately downgradient of a contamination source that had resulted from a leak of an underground waste solvent tank. The study area is the only location at the facility where the source release has contaminated the groundwater with both chlorinated and non-chlorinated groups of VOCs. Several VOC compounds have been detected in the groundwater at this location above their respective Federal Maximum Contaminant Level (MCL). These compounds include actual solvents, such as trichloroethene (TCE) and 1,1,1-trichloroethane (TCA), as well as several of their breakdown products. Prior to the start of the demonstration methane was present and TCE was absent from some of the wells. These observations strongly suggest that anaerobic degradation of TCE was naturally occurring.

The Earth Tech system installed at the study area consisted of eleven monitoring points. These included an injection well, four monitoring wells located within the radius of influence, two monitoring wells located outside of the radius of influence (i.e., one upgradient and one downgradient), and four soil vapor monitoring points. Selection of the specific contaminants and wells to evaluate was based on review of historical site data, results from a pre-demonstration sampling event, and on a statistical analysis. Emphasis was placed on sampling the four monitoring wells located within the radius of influence, which were designated as "critical wells." Four specific contaminants were associated with these wells that exhibited acceptable temporal and spatial variability for evaluating the technology. These "critical analytes" included chloroethane (CA), 1,1-Dichloroethane (1,1-DCA), cis-1,2-Dichloroethene (cis-1,2-DCE), and Vinyl Chloride (VC). TCE was not selected because it did not exhibit acceptable temporal and spatial variability.

The primary objective of the demonstration was to evaluate Earth Tech's claim that there would be a minimum of 75% reduction (with a 0.1 level of significance) in the groundwater concentration of each of the four critical analytes within the zone of influence, following six months of treatment. However, process optimization and modifications resulted in extending the evaluation period to sixteen months. Based on the above-mentioned claim and pre-demonstration data, an experimental design was developed to guide the evaluation. During the baseline and final sampling events, one groundwater sample from each of the four critical wells was collected for VOC analysis daily for seven consecutive days (for a total of 28 samples per event).

Results from the Earth Tech In-Situ Bioremediation Technology demonstration are presented in Table 1 and are based on the 28 baseline and 28 final samples for the four critical analytes. VOC concentrations were determined by EPA SW-846 Method 8260. The results indicate that the targeted 75 percent reduction was achieved or exceeded for two of the four critical compounds, from baseline to final events.

Table 1. Groundwater Results.

Target Compound	Contaminant Concentration (µg/L)[1]		Average Percent Reduction	Statistically Significant Percent Reduction[2]
	Baseline	**Final**		
CA	330	210	36	4
1,1-DCA	960	190	80	71
cis-1,2-DCE	3,100	90	97	95
VC	1,100	45	96	92

[1] Values are the average of 28 results from four wells, and rounded to two significant digits.

[2] Percent reductions shown represent the Lower Confidence Limit (LCL) for the Average Percent Reductions, with a 0.1 level of significance.

An Innovative Technology Evaluation Report (ITER) describing the complete demonstration will be available in the near future. For further information please contact the following:

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