KEY FINDINGS

Evaluation of a Passive Approach to Treat Large, Dilute Chlorinated VOC Groundwater Plumes

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INTRODUCTION

One of the greatest challenges remaining for remediating chlorinated volatile organic compounds (CVOC) at Department of Defense sites is the treatment and/or control of large, dilute plumes. Current approaches to addressing this challenge are typically long-term and have high capital, operation, and maintenance costs. Cometabolism is showing significant promise in this area because organisms grow aerobically on a supplied substrate (e.g., propane or methane) rather than the trace chemicals, allowing good degradation kinetics, minimal impacts to aquifer geochemistry, and the ability to achieve part-per-trillion chemical concentrations. The key objective of this ESTCP-funded project was to demonstrate effective *in situ* cometabolic treatment of a large, dilute CVOC plume using an approach that is cost effective.

TECHNOLOGY APPROACH

The underlying approach of gas biosparging using primary cometabolic substrates is mature, cost effective, and can be safely applied in several different configurations based on site conditions. The fundamental concepts supporting this field demonstration were (1) the utilization of aerobic cometabolism for *in situ* degradation of an environmental pollutant, and (2) distribution of gases in the subsurface to stimulate pollutant biodegradation (Figure 1). This project entailed cometabolic biosparging using a line of sparge wells installed perpendicular to groundwater flow across the width of a large, dilute CVOC plume downgradient of Building 324 at the former Myrtle Beach Air Force Base in SC (Figures 2 and 3). The 210-foot-wide groundwater plume, with *cis*-1,2-dichloroethene (*cis*-DCE) and vinyl chloride (VC) concentrations exceeding federal maximum contaminant levels (MCL) was successfully treated as it flowed through a biologically active zone (i.e., biobarrier) created by sparging oxygen, an alkane gaseous substrate (propane), and a gaseous nutrient (ammonia). The biosparging system, process controls, and system monitoring equipment were powered by an off-the-grid solar energy system (Figure 2). Oxygen, propane, and ammonia were stored on site in cylinders, and configured to provide the appropriate delivery pressures and flows. Sparging of the gases was performed at a single well at a time, to minimize instantaneous flows required.

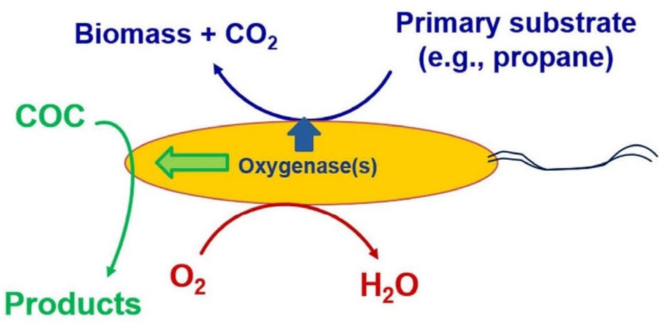

Figure 1: Schematic of Cometabolic Biodegradation

APPLICATION

Due to the vertical anisotropy of the aquifer observed during site characterization activities, the biosparging system design included 22 sparge wells screened across three vertical depth intervals to effectively distribute gaseous amendments. An extensive monitoring network, consisting of 27 monitoring wells, 6 vapor probes, and 4 dedicated dissolved oxygen probes were installed, and construction of the biosparging system was completed in mid-July of 2019 (Figure 2 and Figure 3). Startup of the biosparging system occurred in late July, with oxygen-only sparging cycles being performed for several weeks to establish aerobic conditions within the aquifer. Propane and ammonia sparging cycles began in late September 2019 and continued until September 2020. Upon completion of system optimization, appreciable decreases in both *cis*-DCE and VC groundwater concentrations were observed at the monitoring wells located within and downgradient of the biobarrier, with concentrations in most of the downgradient wells consistently measuring below MCL.

Figure 2: Solar-Powered Biosparging Treatment System

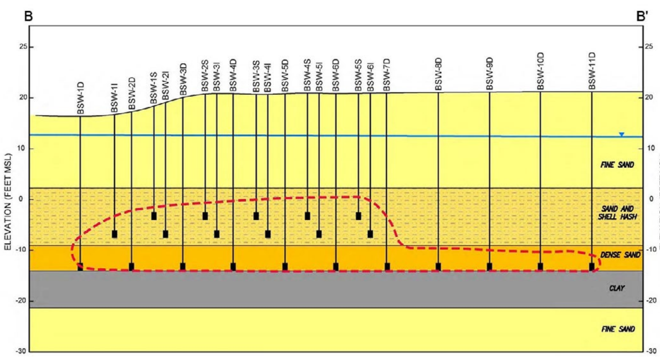

Figure 3: Cross Section of Biosparging Well Layout

RESULTS

Laboratory treatability studies performed with aquifer materials indicated that propane was the most effective cometabolic substrate for stimulating cometabolic degradation of site chemicals and that nutrient addition would be required for effective treatment.

Phase 1 of the field demonstration lasted 67 days and included oxygen-only sparging to both achieve aerobic conditions within the treatment zone, and to evaluate potential stripping of target CVOC. Phase 2 (treatment phase) lasted 355 days and included regular sparging of oxygen, propane and ammonia gasses. Appreciable decreases in *cis*-DCE and VC were observed starting approximately 2.5 to 3 months after initiating propane and ammonia biosparging, after sufficient biomass growth had occurred within the aquifer. Decreases in *cis*-DCE concentrations were observed in 20 of the 22 wells located within and downgradient of the biobarrier, with concentrations at all 22 wells consistently below the MCL of 70 µg/L between days 181 and 422 of the demonstration. A significant decrease in *cis*-DCE mass flux was observed through and downgradient of the biobarrier by day 218, confirming mass loss due to biodegradation. After some system operational changes, this mass loss increased further by day 294 and appeared relatively constant during operations thereafter. The estimated decline in the mass flux of *cis*-DCE was ~ 70-fold due to barrier operation from day 294 to the end of the study.

VC concentrations were below the MCL of 2 µg/L at 15 of the 18 wells by day 294 and remained low for the remainder of the field demonstration. Decreases in the mass flux of VC was observed starting at day 218. Even lower fluxes of VC (after treatment) may have occurred, but due to analytical detections limits (practical quantitation limit of 1 µg/L), these could not be fully quantified. VC concentrations remained below the MCL at 16 of the 18 wells during the final performance sampling event conducted on day 422.

The average *cis*-DCE and VC concentrations measured at wells located 25 ft downgradient of the sparge wells during baseline sampling (day 5) and the final performance monitoring event (day 422) showed a 98% and a 92% decrease. *cis*-DCE and VC generally returned to near baseline concentrations (or in the case of VC, higher than baseline) within 105 days after system shut-down due to the absence of oxygen and cometabolic substrate addition (and possibly nutrient addition), as the degradative activity of the propane oxidizing bacteria (or other bacteria capable of aerobically degrading VC) that were grown within the treatment zone ceased, and impacted groundwater flowing through this area was no longer being treated.

SUMMARY

The data from this ESTCP field demonstration clearly show that propane, ammonia, and oxygen biosparging can be an effective approach to reduce and maintain concentrations of CVOC, such as *cis*-DCE and VC, below relevant MCL. The off-the-grid solar powered biosparging system proved to be highly reliable, simple to operate and maintain, and economical for dilute plume treatment. For many large, dilute plume applications, this type of biosparging system is expected to be significantly less expensive to install and operate than a conventional pump and treat system or other *in situ* approaches, such as a zero valent iron barrier for groundwater treatment.

Point of Contact

David R. Lippincott, PG
david.lippincott@aptim.com
(601) 634-3652

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