DEPARTMENT OF THE AIR FORCE
HEADQUARTERS 377TH AIR BASE WING (AFMC)

ENTERED

RECEIVED
JUL 13 2015
NMED
Hazardous Waste Bureau

Colonel Eric H. Froehlich
377 ABW/CC
2000 Wyoming Blvd SE
Kirtland AFB, NM 87117-5600

JUL 09 2015

Mr. John Kieling, Manager
Hazardous Waste Bureau (HWB)
New Mexico Environment Department (NMED)
2905 Rodeo Park Road
Santa Fe, NM 87505

Dear Mr. Kieling

Attached please find a *Technical Memorandum for a Conceptual Pilot Test – Enhanced Anaerobic Bioremediation of EDB* dated July 2015. This memorandum has been prepared to describe activities and request New Mexico Environment Department comments on the proposed pilot test of a groundwater plume remediation technology associated with ST-106 and SS-111.

Please contact Mr. L. Wayne Bitner at (505) 853-3484 or at ludie.bitner@us.af.mil or Mr. Scott Clark (505) 846-9017 or at scott.clark@us.af.mil if you have questions.

Sincerely

ERIC H. FROEHLICH, Colonel, USAF
Commander

Attachment: Technical Memorandum: Conceptual Pilot Test – Enhanced Anaerobic Bioremediation of EDB dated July 2015

cc:
NMED-EHD (Roberts, McQuillan)
NMED (Longmire)
NMED-HWB (Kieling, Cobrain, McDonald)
NMED-GWQB (Cook, Bustamante, Huddleson)
NMED-PSTB (Reuter)
NMED-OGC (Kendall)
EPA Region 6 (King, Ellinger)
AFCEC-CZRX (Bodour)
USACE-ABQ District Office (Simpler, McBee, Phaneuf)
Public Info Repository, AR/IR, and File

KAFB4304

Technical Memorandum:
Conceptual Pilot Test – Enhanced Anaerobic Bioremediation of EDB

This Technical Memorandum has been prepared by CB&I Federal Services LLC (CB&I) to describe a "conceptual" pilot test that is being proposed for implementation at Kirtland Air Force Base (AFB). The pilot test would be performed as part of the Department of Defense Environmental Security Technology Certification Program (ESTCP) funded project ER-201331 entitled, "Natural Attenuation and Biostimulation for In Situ Treatment of 1,2-Dibromoethane (EDB)." One key objective of this ESTCP project is to demonstrate enhanced in situ bioremediation (ISB) of EDB under anaerobic conditions. The information provided herein has been provided to facilitate communication among CB&I, the Air Force Civil Engineer Center, and the New Mexico Environment Department (NMED) to achieve consensus of the approaches, and to obtain the necessary approvals to move the pilot test forward.

Introduction

The pilot test described herein demonstrates the feasibility of anaerobic ISB for treating EDB at Kirtland AFB, as well as generating data to contribute to the scientific understanding of EDB bioremediation at other EDB and fuel co-contaminated sites. To effectively create an in situ treatment zone, groundwater must be withdrawn from one location, amended with nontoxic compounds as described below, and then reinjected at a location close enough to the extraction well to effect groundwater circulation in the aquifer.

The pilot test approach and the amendments described below are compatible with the anaerobic geochemical conditions that currently exist at the Kirtland AFB Bulk Fuels Facility (BFF) site, and implementing the pilot test would not adversely impact the aquifer geochemistry or mineralogy. The preservation of anaerobic conditions would both minimize the risk of forming iron and manganese oxide phases that might affect the hydraulic performance of the aquifer, and reduce the risk of additional mobilization of contaminants. Aquifer hydraulic properties (i.e., porosity/hydraulic conductivity) may be altered by growth of microorganisms following the introduction of amendments, but dosing of amendments would be controlled to minimize these effects. Microbial growth in the subsurface should correspond to increased consumption of EDB and other contaminants of concern, which would be monitored during the pilot test. System operations would be monitored by control systems with remote capabilities.

Regulatory Requirements

Two pilot test-related issues that would require NMED approval are as follows:

1. The potential need to add nontoxic amendments (e.g., diammonium phosphate (DAP), sodium lactate, SDC-9 dehalogenating microbial culture) to Kirtland AFB BFF site groundwater.

2. The need to recirculate water, which would entail extracting contaminated groundwater, adding the necessary amendments, and then reinjecting the amended water within 150 feet of, and at the same depth from which, the groundwater was extracted. Recirculation would be performed periodically to facilitate introducing and mixing of amendments between the extraction and injection wells, and to develop an in situ treatment zone.

The following sections provide brief details on the background of the ESTCP project, the pilot test locations and design, the amendments needed to promote and sustain anaerobic EDB biodegradation, the four pilot test phases, pilot test monitoring methods, and the reporting requirements.

ESTCP Project Background

The pilot test would be performed as part of an ESTCP project to demonstrate an innovative remediation technology for EDB, a key driver of remediation efforts at Kirtland AFB. Funding for the ESTCP project is independent from other work being performed by CB&I at Kirtland AFB. ESTCP was established in 1995 to promote the transfer of innovative technologies, including remediation technologies, from proof-of-concept to practical application. Communication and transfer of knowledge is essential to the success of the ESTCP program and its individual projects. In addition to communicating pilot test results through ESTCP reports and peer-reviewed scientific journal articles, results of the pilot test would be shared with Kirtland AFB working groups and regulators, who would facilitate communication with the local community and ensure that results help inform ongoing remediation efforts at Kirtland AFB.

Pilot Test Location and Design

Kirtland AFB is a good test location for demonstrating anaerobic ISB of EDB for several reasons.

1. Kirtland AFB, and the BFF site in particular, has been very well characterized, and hydrogeological models are available to facilitate planning and interpretation of results.

2. Certain areas of the BFF site aquifer are anaerobic with elevated levels of EDB, which should facilitate observation of enhanced EDB degradation.

3. Due to ongoing BFF work, CB&I has a local presence to implement this work.

4. Results of this ESTCP study would be directly applicable to the work being performed at Kirtland AFB, potentially leading to rapid and efficient transfer of an innovative technology to full-scale use in the field.

The pilot test would be performed where previous site characterization efforts indicate elevated concentrations of EDB (e.g., concentrations greater than 5.0 micrograms per liter (µg/L). The pilot test would require anaerobic field conditions, and characterization at Kirtland AFB indicates that such conditions are commonly co-located with elevated EDB concentrations. The pilot test would require four to five closely spaced wells as illustrated in Figure 1. The outermost pair of wells would be spaced 100 to 150 feet apart (based on groundwater modeling) and would be used to periodically recirculate groundwater and amendments during the pilot test. As described below, recirculation would not be continuous, but rather only used to distribute amendments in the aquifer between extraction and injection wells, and would be shut down for evaluation of treatment effectiveness. The intermediate wells would be used to monitor the performance of the technology. To ensure security and safety during the pilot test, the system would be installed on Kirtland AFB property, with the exact location determined based on discussions with CB&I, Air Force Civil Engineer Center, the NMED, ESTCP, and other stakeholders.

The pilot test described herein would demonstrate the application of ISB technology by anaerobic biostimulation and, if necessary, bioaugmentation with a dehalogenating microbial culture to enhance in situ EDB degradation at the BFF site. ISB with and without bioaugmentation is a common remedial approach to treat chlorinated solvents such as trichloroethene, and is a promising and innovative technology for promoting the degradation of EDB to nontoxic products. Recent analyses of the groundwater microbial community at Kirtland AFB using Microbial Insight's QuantArray protocol indicated that microorganisms believed capable of EDB dehalogenation are present in the subsurface (Figure 2). Additionally, while laboratory treatability testing using Kirtland AFB field materials continues, results to date show that bioaugmentation with a known dehalogenating culture (SDC-9) can significantly enhance EDB degradation rates (Figure 3). These results indicate that anaerobic ISB may be successful at enhancing rates of EDB degradation at Kirtland AFB. The pilot test is designed to validate the anaerobic ISB concept at a larger field scale.

Pilot Test Amendments

The addition of amendments would be facilitated by periodic groundwater circulation between closely-spaced wells. These amendments could include the following:

1. **Inorganic Nutrients**—These nutrients would consist of nitrogen (N) and phosphorous (P) from diammonium phosphate [also called DAP or $(NH_4)_2HPO_4$]. In environments with high total organic carbon, inadequate quantities of N or P can limit EDB and/or fuel hydrocarbon biodegradation.

2. **Fermentable Substrate**—A fermentable substrate, such as sodium lactate, would be added to generate acetate and hydrogen, both of which are necessary for the growth and activity of many dehalogenating organisms.

3. **Bioaugmentation Culture**—If the indigenous microbial community cannot be stimulated to degrade EDB within a defined period, a bioaugmentation culture, such as SDC-9, which is proven to degrade EDB to less than 0.04 µg/L, would be added to the aquifer. Alternatively, CB&I has recently cultured an EDB-degrading anaerobic culture from Kirtland AFB aquifer samples that could be used for bioaugmentation if additional research shows the culture to be suitable. Crucial properties of this culture, including its ability to be grown to high densities or its ability to degrade EDB to less than 1 µg/L, have yet to be evaluated.

Amendments would be stored and mixed in locations with controlled access.

Pilot Test Phases

The pilot test would be performed through four sequential phases of increasing complexity.

Phase 1: Unamended Steady-State—After installation of the wells required for testing and initial sampling of wells to establish pre-test baseline conditions, groundwater without amendments would be recirculated until approximate steady-state conditions are reached. This effort would mix water within the treatment zone of the pilot test and allow for new baseline measurements used later to help evaluate treatment effectiveness during the biostimulation and bioaugmentation phases. This preliminary recirculation phase is anticipated to take approximately 4 weeks. A conservative tracer (e.g., deuterated water, fluorescein) would be used to evaluate subsurface transport and mixing characteristics. An additional sampling event 2 to 4 weeks after recirculation activities have ceased would be performed to verify baseline conditions and observe variability.

Phase 2: Biostimulation—Groundwater amended with inorganic nutrients (e.g., DAP) and easily fermentable substrate (e.g., sodium lactate) would be recirculated to distribute amendments throughout the subsurface treatment zone. The goal of these amendments is to stimulate activity of native microbial populations capable of dehalogenating EDB. Active recirculation of groundwater during this phase is anticipated to take approximately 4 weeks. After active recirculation, groundwater in the treatment zone would be monitored for approximately 12 weeks to evaluate whether microorganisms are stimulated and EDB degradation is enhanced.

Phase 3 (if necessary): Bioaugmentation—If the activity of native EDB-degrading microorganisms does not increase during Phase 2 of the pilot test, and if enhanced EDB degradation is not otherwise indicated, a bioaugmentation culture would be added along with additional nutrients and lactate. Active recirculation of groundwater during this phase is anticipated to take approximately 4 weeks. After active recirculation, groundwater in the treatment zone would be monitored for an additional 12 weeks to evaluate whether microorganisms are stimulated and EDB degradation is enhanced.

Phase 4: Continued Monitoring or Repurposing of Well Network Infrastructure for Other In Situ Testing—Biostimulation, or bioaugmentation if necessary, is anticipated to result in enhanced in situ EDB degradation. If enhanced degradation is indicated, the pilot test system would be monitored for an extended period of time (at least 6 months) to verify continued EDB degradation, and to observe potential rebound, if any, of EDB concentrations. If enhanced EDB degradation is not observed during the pilot test, the pilot test well infrastructure could be repurposed for other in situ testing, such as aerobic treatment. Testing of other in situ treatment options falls outside the scope of the ESTCP work described in this Technical Memorandum.

Each phase described above would include a period of groundwater recirculation followed by a longer period of monitoring. If enhanced degradation of EDB is observed but stalls due to apparent consumption of amendments, more amendments may be provided through additional recirculation of groundwater during the appropriate phase, followed by further monitoring.

Pilot Test Monitoring

Pilot test monitoring would include measuring field parameters (e.g., pH, temperature, dissolved oxygen, oxidation-reduction potential, and specific conductance) using field meters. Aqueous samples would be collected to monitor EDB, volatile organic compounds, dissolved gases, dissolved iron and manganese, anions (including bromide), and alkalinity. In addition, samples would be collected at select times to conduct compound-specific stable isotope analysis of EDB carbon ($^{13}C/^{12}C$), and to evaluate microbial community structure, primarily populations of specific dehalogenating bacteria.

Reporting

Interim status meetings (conference calls) will be scheduled to update stakeholders on progress and recommendations to move from one phase to the next.

A draft and final Project Report and Cost-and-Performance Report will be prepared and submitted as required by ESTCP at the end of the project activities. The reports will follow ESTCP guidelines and describe all relevant findings of the study. Once approved by ESTCP, these reports will be posted to the ESTCP website. It also is anticipated that the work performed here will lead to the preparation and submission of one or more manuscripts for publication in peer-reviewed scientific journals. A final debrief will be prepared and presented to ESTCP at the end of the project.

Figure 1. Schematic of Recirculation and Monitoring Wells Necessary for the Proposed Conceptual Pilot Test

The outermost wells would be on the order of 100 to 150 feet apart. The most downgradient well would be used to extract groundwater, and the most upgradient well would be used to reinject the groundwater. The wells located between extraction and injection wells would be used to monitor performance of treatment.

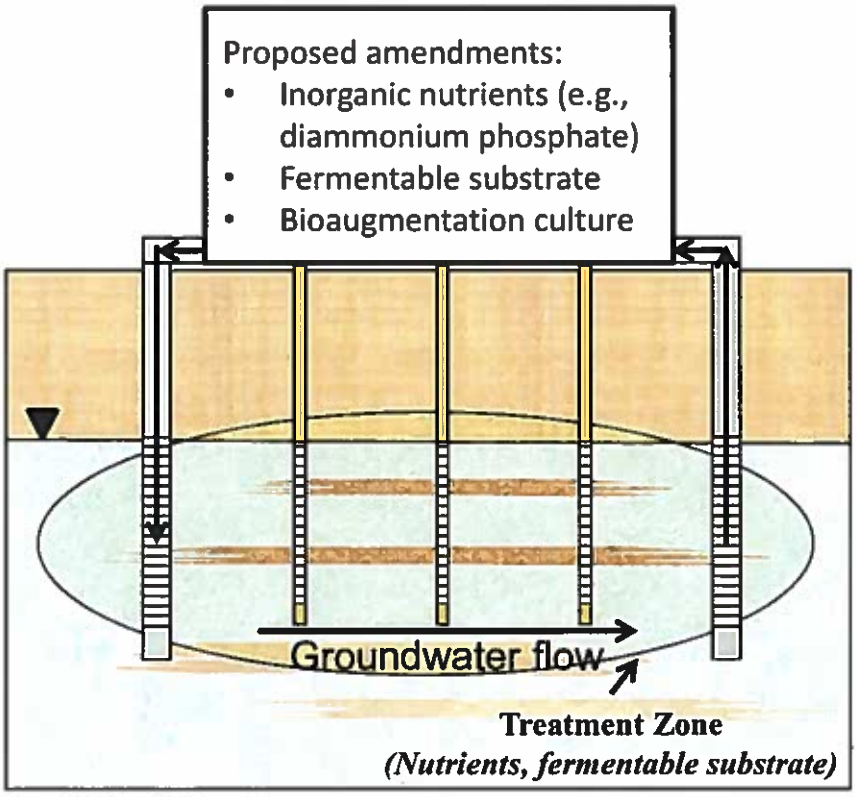
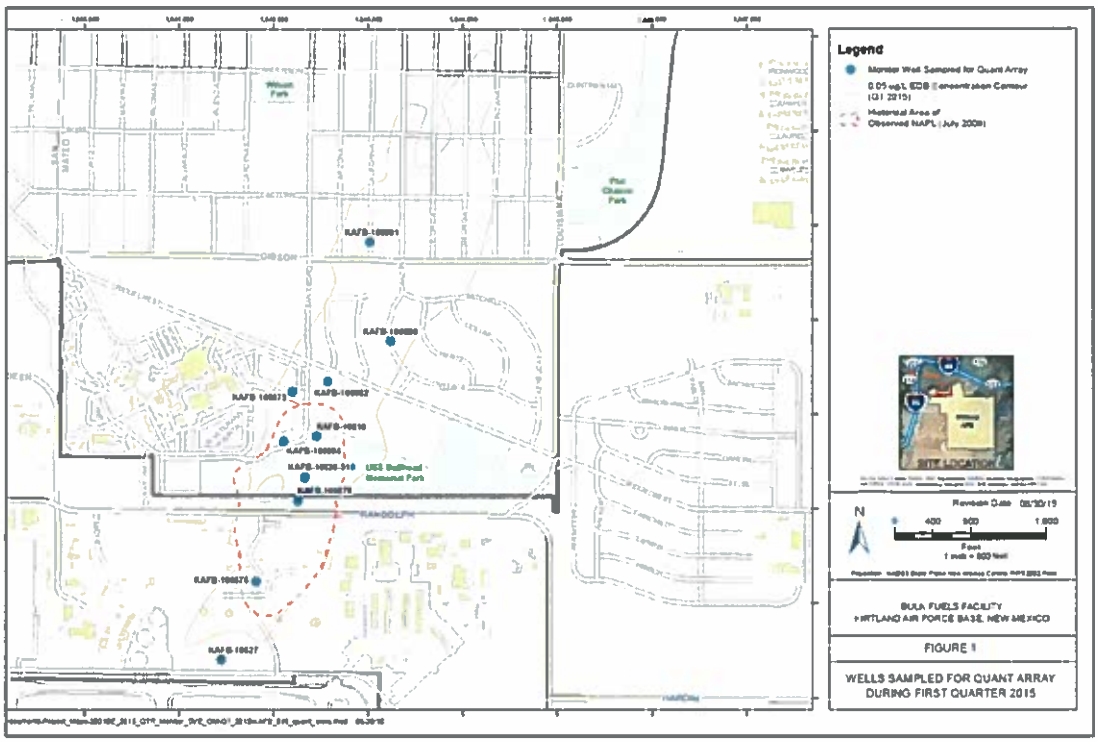
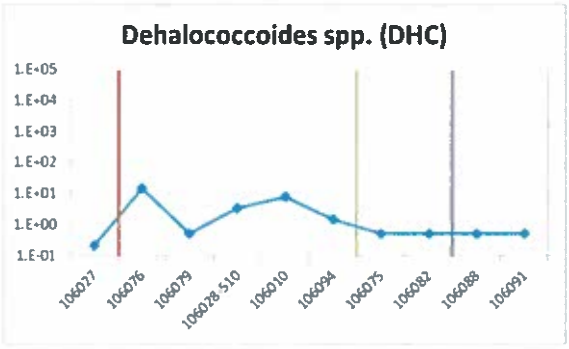
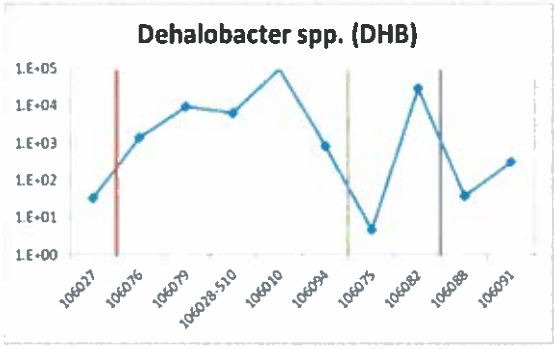


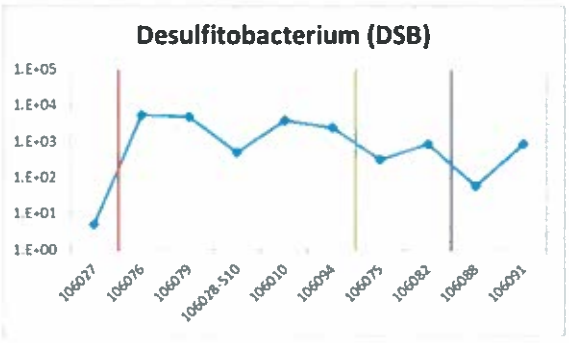
Figure 2. Population Densities of Specific Dehalogenating Organisms in a Transect Across the KAFB BFF Site

The wells included in the transect are shown in the top panel. The specific organisms shown in the graphs at the bottom of the figure are those reasonably anticipated to be capable of degrading halogenated ethanes, such as EDB. The numbers provided are cells per milliliter of groundwater. The data show low levels of *Dehalococcoides*, but moderate populations of the three other dehalogenating species.









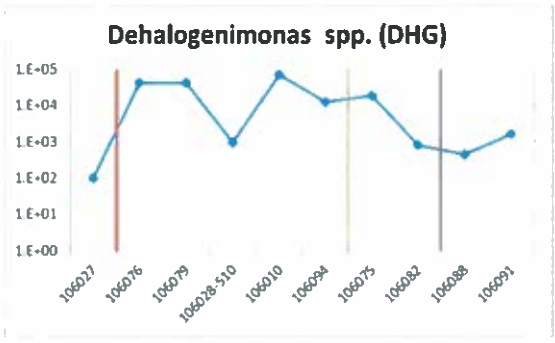


Figure 3. Concentrations of EDB in Anaerobic Microcosms Prepared with Aquifer Samples Collected from the BFF Site in the NAPL Area

The only treatment showing appreciable degradation of EDB was that amended with the dehalogenating culture SDC-9. EDB concentrations were below the detection limit of 0.04 µg/L throughout most of the study in this treatment. During Month 5, the analytical detection limit was much greater due to greater sample dilution by the analytical laboratory, thus suggesting that the observed increase to 3.9 µg/L may be spurious.