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Bioremediation of Chlorinated Solvents Consortium

RTDF

Remediation Technologies Development Forum

Current RTDF Action Teams

Bioremediation Consortium

IINERT Soil-Metals Action Team

Permeable Reactive Barriers Action Team

Phytoremediation of Organics Action Team

Sediments Remediation Action Team

The Bioremediation of Chlorinated Solvents Consortium is one of the five current Action Teams of the Remediation Technologies Development Forum (RTDF). The RTDF was created in 1992 by the U.S. Environmental Protection Agency (EPA) to foster collaboration between the public and private sectors in developing innovative solutions to mutual hazardous waste problems. The Bioremediation Consortium was established in May 1993, when representatives from various companies, universities, the EPA, the Department of Defense (DOD), and the Department of Energy (DOE) met to discuss their shared interest in developing *in situ* bioremediation technologies to degrade chlorinated solvents in soils and ground water. As a result of that first meeting, the industrial partners of the Bioremediation Consortium—DuPont, Dow, General Electric, Monsanto, Zeneca, and Ciba-Geigy—signed a research agreement in September 1994. Agreements then were negotiated with EPA, the Air Force, and DOE to facilitate collaboration between the public and private sectors on the planned research projects. Two additional companies, Beak International and ICI Americas, joined the Bioremediation Consortium in Spring 1996. Recent changes to the Bioremediation Consortium include the withdrawal of Monsanto and the addition of GeoSyntec Consultants, replacing Beak International.

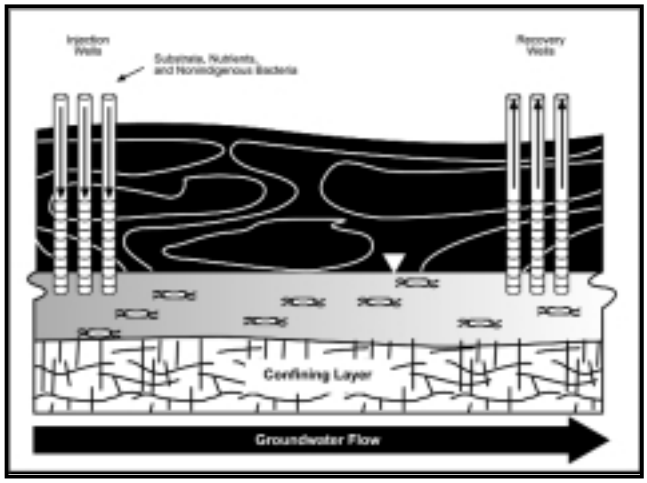
The Problem of Concern

Chlorinated solvents are common contaminants resulting from industrial and government operations. Used as solvents and degreasers, they are typically found in the soils and ground water near manufacturing, maintenance, and service installations around the world. Biodegradation of chlorinated solvents occurs naturally to varying degrees at many sites. A better understanding of how to predict and manage these degradation processes is needed to ensure their use as cost-effective, practical solutions.

The Consortium's Mission

The mission of the RTDF Bioremediation Consortium is to accelerate the development of the most cost-effective *in situ* bioremediation processes for degrading chlorinated solvents. Consortium members jointly participate in the research, development, demonstration, and evaluation efforts necessary to achieve public and regulatory acceptance of these biological processes. In addition, the data generated and experience gained by the Consortium in conducting field studies with these processes will be used to develop guidelines for their use at other contaminated sites.

Accelerated Anaerobic Biodegradation



Processes Under study

The Consortium focuses on three *in situ* bioremediation processes: cometabolic bioventing (for treatment in the vadose zone), intrinsic bioremediation (for treatment of the bulk of a plume), and accelerated anaerobic biodegradation (for treatment of more concentrated areas of a plume). These technologies are environmentally friendly; they cause minimal disturbance to the site as they require few surface structures. They can be less costly than conventional pumping and treating. The Consortium initiated Phase I field tests of the three processes at Dover Air Force Base (AFB) in Dover, Delaware, in early 1995. Planning is underway to conduct Phase II field studies for each of the processes.

Cometabolic Bioventing

Laboratory studies have shown that aerobic degradation of trichloroethylene (TCE) in soils occurs only in the presence of a cometabolite, such as toluene, propane, or methane. Cometabolic bioventing uses a technique, similar to methods currently used in bioventing technology, to efficiently deliver oxygen and a cometabolite to the vadose zone in order to remediate TCE. This technology appears to have great promise. The objective of the RTDF cometabolic bioventing study is to develop a cost-effective process that promotes the cometabolic bioremediation of TCE and other chlorinated solvents.

Intrinsic Bioremediation

Intrinsic bioremediation, or natural attenuation, of chlorinated solvents in ground water can occur at sites where indigenous microbial populations are present that can degrade these chemicals. Certain microorganisms are capable of detoxifying chlorinated methanes, ethanes, ethylenes, and many other compounds by reductive dehalogenation or by oxidation. These processes can result in complete biodegradation to innocuous end products. The objective of the natural attenuation research effort is to quantitatively determine where, at what rate, and under what conditions intrinsic bioremediation occurs.

Accelerated Anaerobic Biodegradation

Complete *in situ* anaerobic dechlorination requires that the necessary microorganisms are present. The dechlorination is typically limited by the availability of food and nutrients for microbial growth. The purpose of the accelerated anaerobic degradation study is to (1) understand the microorganisms involved, (2) identify the nutritional requirements, (3) determine how to effectively deliver the nutrients, and (4) determine how to effectively deliver microorganisms to the aquifer, when needed. Other study objectives include determining which electron donors and acceptors best support anaerobic bioremediation; optimizing the chlorocarbon destruction rate; determining what factors control the degradation kinetics; and gathering cost and performance data in order to facilitate the use of this technology at other sites.

Consortium Members' Roles

Every Consortium member plays a specific role in the collaborative efforts for the three bioremediation processes. Each organization brings particular knowledge and expertise, as well as laboratory research, field studies, and resources necessary to conduct the projects and evaluate the effectiveness of the technologies.

The companies are sharing proprietary information, patented technologies, and their collective understanding and experience in bioremediation mechanisms and kinetics, hydrogeology, and nutrient delivery systems to support the development and testing of the three bioremediation processes.

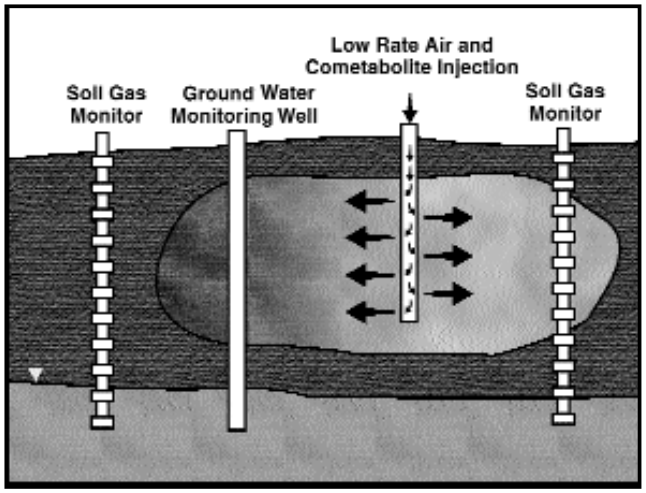
EPA's National Risk Management Research Laboratory (NRMRL) in Cincinnati, Ohio, is applying its knowledge and experience in developing bioventing processes to support the laboratory and field testing efforts for the cometabolic

bioventing study. NRMRL also provides technical assistance to the ground-water projects. The Air Force brings its expertise in bioremediation and bioventing, as well as support for site characterization and field work at Dover AFB. DOE is applying its substantial bioremediation expertise and laboratory experience, as well as tools for microbial characterization that will be useful in these studies.

Accomplishments

Cometabolic Bioventing. The Consortium conducted a Phase I cometabolic bioventing study at the Bldg. 719 site at Dover AFB, Delaware, a jet engine maintenance facility with TCE- and

Cometabolic Bioventing



trichloroethane (TCA)-contaminated soil. Prior to the Phase I field demonstration, microcosm and column tests were performed using soil from the Dover AFB site to identify substrates. The results of these tests indicated that co-substrates propane and toluene stimulated TCE biodegradation at relatively fast rates and that propane stimulated cometabolic biodegradation of TCA. Propane was chosen to be used as the co-substrate for the field pilot test. The Consortium designed, installed, and began operating the pilot-scale field system in May 1998. The system consisted of a test plot approximately 30 ft long, 20 ft wide, and 10 ft deep, with three injection wells screened to a depth of 10 ft below ground surface (bgs). An air sparge blower was used to inject a mixture of air and propane (300 ppm in air) at a rate of 1 ft3/minute. The Phase I study will be completed late in 1999.

The Consortium has chosen Operable Unit 2, Hill Air Force Base (AFB) in Utah for Phase II cometabolic bioventing work. Laboratory microcosm and soil column tests, conducted using site soils, showed that TCE and TCA could be biodegraded best in the presence of cosubstrate propane. Preliminary field design data was collected at the site in early 1999.

Intrinsic Bioremediation. The Consortium conducted a four-year Phase I intrinsic bioremediation study at the Area 6 site at Dover AFB, Delaware, where chloroethylenes are present in shallow ground water. Key to selection of Dover AFB as the test site was the presence of an active microbial population, which was evidenced by the detection of degradation products at the site. Results of the study indicate that contaminant concentrations have decreased markedly over the test period. The Consortium published a report in 1999 related to the the Phase 1 natural attenuation work. "Groundwater Geochemistry of Area 6, Dover Air Force Base, Dover, Delaware." The report is available from the National Technical Information Service (NTIS). The Order Number is PB99-162430/XAB.

The Consortium also conducted a detailed analysis of ground-water data from site-monitoring wells to calculate the apparent flux of chlorinated compounds across the plume. Results of this analysis are being compared with similar calculations made using ground-water data collected as part of an elaborate "transect" study involving over 100 discrete ground-water samples, and Consortium members are evaluating these two methods of flux calculation.

In addition, the Consortium used data from both field and laboratory studies to develop a predictive natural attenuation model that relates the measured degradation rates to the expected time course and outcome of intrinsic bioremediation. The model is in the public domain and can be used on personal computers.

Industrial members of the Consortium, in cooperation with the Western Governors Association and the Interstate Technology Regulatory Cooperation (ITRC) Work Group, have published the Natural Attenuation of Chlorinated Solvents Principles and Practices Manual. With ITRC sponsorship, the Consortium's industrial members also developed a two-day "Natural Attenuation of Chlorinated Solvents in Ground Water" training course. The course was delivered at several locations around the

country during 1999. Both the manual and information on course offerings are available on the Internet at www.biotreat.state.pa.us.

Accelerated Anaerobic Biodegradation. The Consortium conducted a proof of technology pilot test at Dover AFB from September 1996 to March 1998. The system (shown below left) included three extraction wells and three injection wells, each screened to a depth of 38-48 ft bgs. These wells formed a rectangular, hydraulically-controlled cell that was 40 ft. wide and 60 ft. long. The pilot system was designed to operate as a "closed loop" recirculation cell, providing a residence time of about 60 days. Sodium lactate, ammonia, and phosphate were injected into extracted ground water. During the first five months of operation, the concentration of TCE gradually decreased, cis-dichloroethylene (cis-DCE) showed a slight increase, and there was no increase for vinyl chloride or ethylene, indicating that limited dechlorination was occurring. After increasing the substrate feed concentration to 200 mg/L, an increase was noted in DCE concentrations, along with a decrease in TCE concentrations, however, there was no evidence that dechlorination beyond DCE was occurring. In June 1997, 351 liters of an aqueous culture from a DOE site in Largo Florida was injected into the recirculation cell (bioaugmentation). By September 1997, vinyl chloride and ethylene began appearing in wells closest to the injection wells. By March 1998, all TCE and DCE in the ground water were converted to ethylene, and between 75% and 80% of the TCE and DCE had been recovered as ethylene. The Consortium is analyzing final results of the pilot test and testing parameters involved with technology scale up.

The Consortium's Plans

Research efforts on the three Phase I projects will continue through 1999. Performance data from the Phase I cometabolic bioventing study are being compiled and are expected to be available late in 1999. The Phase II work at Hill AFB began in summer 1999. In addition, a mathematical model is being developed to simulate cometabolic bioventing and will be tested against the monitoring data generated in the field test.

The Consortium has selected a site in Niagara Falls, New York, for research into the natural attenuation of source areas for the Phase II intrinsic bioremediation work. The Consortium also is examining the importance of natural attenuation at Kelly Air Force Base, Texas, as part of its Phase II work. In addition, the Consortium is involved, through the U.S. Department of Defense Environmental Security Technologies Certification Program (ESTCP) in demonstrating bioaugmentation at Fallon Naval Air Station (NAS), Nevada.

Consortium members are working with the Interstate Technology Regulatory Cooperation (ITRC) Work Group to develop training on accelerated anaerobic biodegradation of chlorinated solvents. Pilot offerings of the training are expected to begin late in 1999.

Consortium Funding Sources

EPA provides the necessary funds and staff to support and facilitate Bioremediation Consortium meetings. Staffing, funding, and equipment needed to develop and test these three bioremediation processes are being provided by the Bioremediation Consortium members. Both EPA and the Air Force work through a Cooperative Research and Development Agreement (CRADA), which allows government agencies to work with industry on collaborative research efforts. DOE has contributed significant funding for the intrinsic bioremediation and accelerated anaerobic biodegradation Phase I projects. The Phase I cometabolic bioventing field study has been primarily funded by the EPA, the Air Force, and Zeneca. Additional funding for Phase II intrinsic bioremediation and cometabolic bioventing projects has been provided by the Chlorine Chemistry Council.

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Remediation Technologies
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