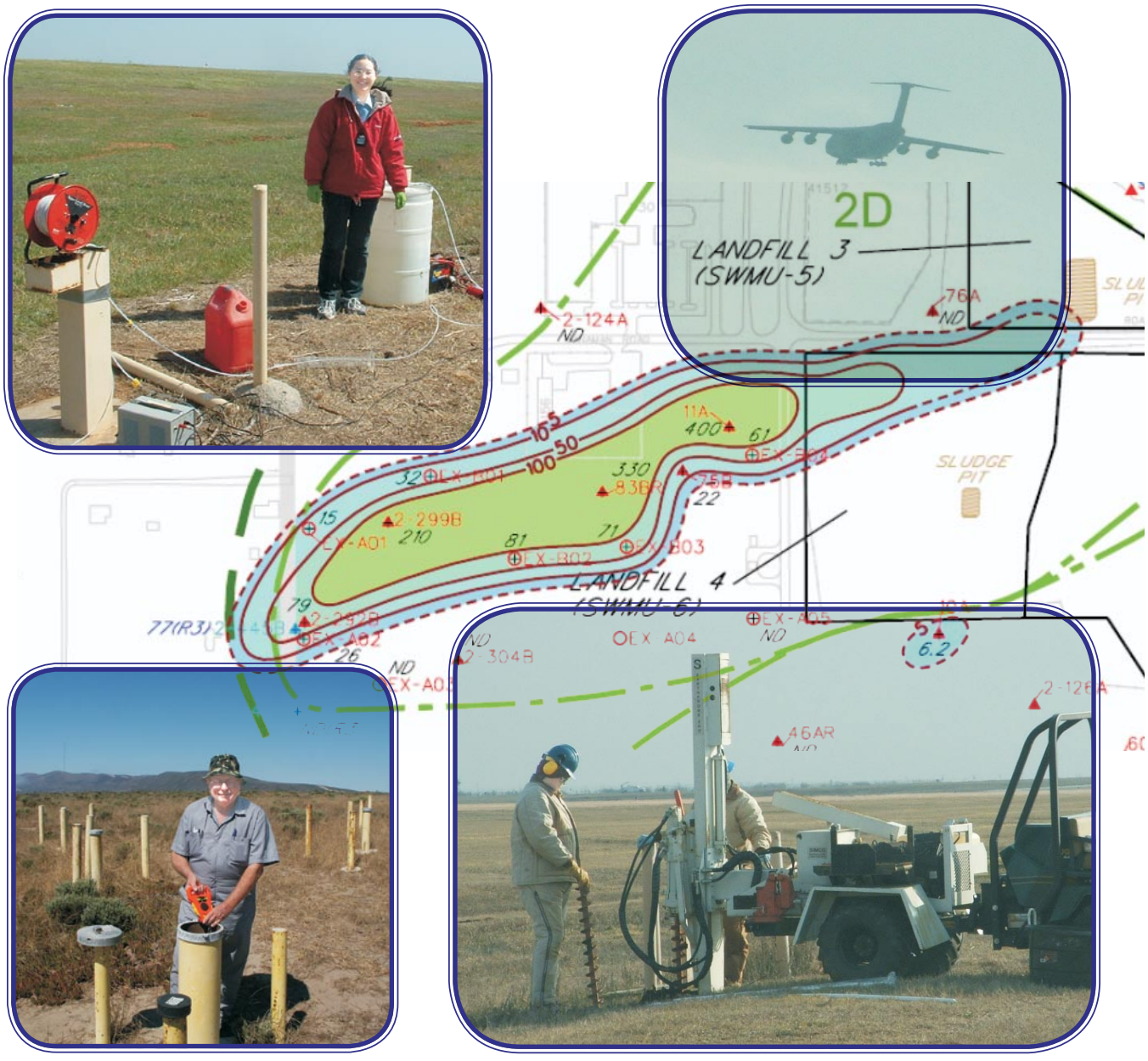
United States Environmental Protection Agency

Evaluation of the Role of *Dehalococcoides* Organisms in the Natural Attenuation of Chlorinated Ethylenes in Ground Water



EPA/600/R-06/029
July 2006

Evaluation of the Role of *Dehalococcoides* Organisms in the Natural Attenuation of Chlorinated Ethylenes in Ground Water

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Support from the U.S. Air Force Center for
Environmental Excellence through
Interagency Agreement # RW-57939566

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Notice

The U.S. Environmental Protection Agency through its Office of Research and Development funded the research described here. This work was conducted under in-house Task 3674, Monitored Natural Attenuation of Chlorinated Solvents, and in association with and with support from the U.S. Air Force Center for Environmental Excellence through Interagency Agreement # RW-57939566, Identification of Processes that Control Natural Attenuation at Chlorinated Solvent Spill Sites. Mention of trade names and commercial products does not constitute endorsement or recommendation for use.

All research projects making conclusions and recommendations based on environmentally related measurements and funded by the U.S. Environmental Protection Agency are required to participate in the Agency Quality Assurance Program. This project was conducted under a Quality Assurance Plan prepared for Task 3674, Monitored Natural Attenuation of Chlorinated Solvents. Work performed by U.S. EPA employees or by the U.S. EPA on-site analytical contractor followed procedures specified in these plans without exception. Information on the plan and documentation of the quality assurance activities and results is available from John T. Wilson.

Foreword

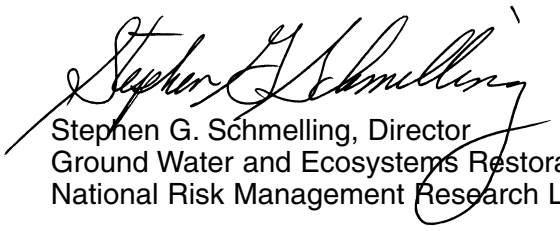
The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threatens human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Chlorinated solvents such as tetrachloroethylene and trichloroethylene are an important category of contaminants in ground water at hazardous waste sites. Frequently, these compounds are subject to natural anaerobic biodegradation in ground water. During anaerobic biodegradation they undergo a sequential biological reductive dechlorination to produce *cis*-dichloroethylene, then vinyl chloride, and finally ethylene or ethane. Although *cis*-dichloroethylene is less hazardous than trichloroethylene or tetrachloroethylene, vinyl chloride is more hazardous. In contrast, ethylene or ethane is not hazardous to humans. If the biological reductive dechlorination is complete, with ethylene or ethane as the final product, then monitored natural attenuation can be used a remedy for the ground water contamination.

In recent years, bacteria that can dechlorinate dichloroethylene to ethylene or ethane have been isolated and characterized. All the strains that can dechlorinate vinyl chloride to ethylene or ethane belong to the genus *Dehalococcoides*. A biochemical assay for DNA specific to the genus *Dehalococcoides* is commercially available. This report provides technical recommendations on the interpretation of the biochemical assay and on the contribution of bacteria in the *Dehalococcoides* group to monitored natural attenuation of chlorinated solvents in ground water.



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Acknowledgments

Formal peer reviews were provided by Dr. Carolyn Acheson with the U.S. EPA Office of Research and Development, National Risk Management Research Laboratory; Dr. Ned Black with U.S. EPA Region 9; Dr. Mitch Lasat with U.S. EPA Office of Research and Development, Office of Science Policy; Dr. Donna Fennell at Rutgers University, New Brunswick, NJ; Dr. James Gossett at Cornell University, Ithaca, NY; Dr. David Ellis with DuPont Company, Wilmington, DE; Dr. Guy Sewell at East Central State University, Ada, OK; and Dr. Andrea Leeson, a SERDP/ESTCP Cleanup Program Manager, Arlington, VA. Courtesy technical reviews were provided by Mr. Philip Dennis, SIREM Operations Manager, GeoSyntec Consultants, Guelph, Ontario, Canada, and by Dr. Margaret Findlay and Dr. Sam Fogel of Bioremediation Consulting, Inc., Watertown, MA.

Abstract

At most hazardous waste sites where monitored natural attenuation (MNA) of chlorinated solvents in ground water is successful as a remedy, the chlorinated solvents are biologically degraded to harmless end products such as ethylene or ethane. Many organisms can degrade chlorinated solvents such as tetrachloroethylene or trichloroethylene, to dichloroethylene and vinyl chloride. This contributes little to risk reduction because vinyl chloride is more toxic and more carcinogenic than tetrachloroethylene or trichloroethylene. The only organisms known to degrade dichloroethylenes and vinyl chloride to ethylene or ethane are members of the *Dehalococcoides* group. As a result, these organisms have a critical role in the evaluation of MNA at chlorinated solvent sites. In recent years, biochemical assays for the presence of DNA from the organisms have become commercially available. These assays are based on the polymerase chain reaction (PCR) for the amplification of DNA extracted from ground water. They are very sensitive and can be very specific.

This report is designed for technical staff in the EPA Regions and in state agencies that require information on the contribution of *Dehalococcoides* bacteria to MNA of chlorinated solvents, and information on the proper application and interpretation of the assays in an evaluation of MNA. This report includes sections on the role of biotransformation in evaluation of MNA of chlorinated solvents, the ecology of microorganisms that transform chlorinated solvents, tools to assay microorganisms that transform chlorinated solvents, the relationship between *Dehalococcoides* DNA in ground water and rates of natural attenuation at field scale, the relationship between geochemical parameters and the occurrence of *Dehalococcoides* DNA in ground water, and the relationship *Dehalococcoides* DNA in ground water and behavior of chlorinated solvents in laboratory treatability studies or microcosm studies done with water from the plume.