Surfactant-Enhanced Biodegradation of Contaminants

Cleanup
CU-731

LEAD AGENCY: U.S. Army

LAB: USAE Waterways Experiment Station

PRINCIPAL INVESTIGATOR: Dr. Herb Fredrickson (601) 634-3716

PROBLEM STATEMENT: Overall Goal: This research will investigate the basic processes limiting the bioavailability of contaminants sorbed to soils and evaluate the applicability of biologically-mediated, desorption- enhancing processes to increase microbial destruction of these contaminants.

The DOD has over 12,000 sites contaminated with a variety of energetic and organic compounds. Long-term persistence of these materials in soils is directly related to poor mobility of the contaminants and to resistance of the contaminant to microbial degradation. Many of these organic contaminants are sorbed onto clays or organic matter in soils. Through a combination of sorption processes, the contaminant may move deep into soil pores and/or clay mineral lattice structures, effectively immobilizing the contaminant. Inability of sorbed contaminants to partition back into the aqueous phase severely limits microbial degradation of contaminants in soil treatment systems. Correspondingly, effective biotreatement for those compounds is impaired because the bacterial are unable to contact the sorbed compound. As a result of these processes, immobilization is a significant problem to overcome in site restoration.

Current remediation technologies are deficient. Incineration is expensive and bioremediation often fails. Mobilization of contaminants is highly desirable for the development of new remediation technologies and improvement of existing technologies. For example, initial research at the U.S. Army Engineer Waterways Experiment Station (WES), the U.S. Environmental Protection Agency Athens Environmental Laboratory (AERL), and the U.S. Naval Surface Weapons Center (NSWC) indicates that certain surfacants can accelerate microbial degradation of TNT and chlorinated aromatic hydrocarbons and the microorganisms produce bioemulsifiers that may promote removal of contaminants previously bound to the soil. Other investigators indicate that enzymes modify certain contaminants that strongly sorb to soil, altering their affinity for soil by modifying the structure of substituents on the contaminant molecule. As a result, an intermediate transformation product having increased solubility may be produced, thus enhancing complete microbial degradation of the contaminant.

Enhancing the effectiveness of bioremediation will require an integrated investigation of the physical, chemical and biological factors affecting sorption of organic contaminants as they relate to bioavailability. The information gained from the 6.1 level basic research can be directly applied to 6.2 level investigations to promote bioremediation technologies.

PROJECT OBJECTIVES: Determine the role of sorption on availability of contaminants to microbial degradation. Reduce costs for microbial treatment of soils in sites contaminated with explosives and other organics by identifying ability of microbially-supported, desorption-enhancing processes to overcome sorption limitations.

STATUS OF PROJECT: Research was initiated to identify basic sorption processes and determine their possible relationship to microbial degradation of contaminants under SERDP in FY 93. This proposed basic research will further develop that effort in conduction with preliminary work supported

under the Environmental Quality and Technology Program. This research is jointly submitted by the US Army (WES) and the US Navy (Naval Surface Warfare Center) and US EPA (ERL-Athens) for SERDP funding.

PROJECT DESCRIPTION: Technical Objectives: Determine the significance of soil sorption on biological availability of representative explosives, Chlorinated pesticides, polychlorinated biphenyls (PCB's) and polycyclic aromatic hydrocarbons (PAH's). Provide procedures to determine the most effective means by which microorganisms overcome sorption limitations. Develop methods to determine applicability of microbiologically-mediated, desorption-enhancing processes to improve microbial destruction of contaminants. Provide this information in a form suitable for use at the 6.2 level.

TECHNICAL APPROACH: Determine the importance of sorption in controlling bioavailability of several organic contaminants of military importance and identify the means microorganisms utilize to overcome these limitations. This will be accomplished in a series of tasks listed below. Critical portions of Tasks II, III, and IV require application of several microbiological and biochemical technologies that are at the cutting edge of present-day research. For this reason, the proposed research could not have been undertaken 2-3 years ago.

a. Task I. Compare diffusion of organic contaminants within soil particles with microbial degradation to determine limiting rates and focus research on the more significant knowledge gaps. Identify suitable systems in which to study processes. Determine presence or absence of biosurfactant and/or bioemulsifier production by key microbial species active in contaminant degradation.

b. Task II. Develop techniques for investigating sorption sites on and diffusion within soil particles. Develop techniques for investigating movement of microorganisms producing biosurfacants and/or bioemulsifiers processes having sorption-modifying capabilities.

c. Task III. Develop predictive sorption kinetics models to evaluate importance of sorption to bioavailability and select the most appropriate procedures for determining sorption limitations. Develop a data base for verification of general predictive techniques with soils having a wide range of properties.

    (1) Procedures for determining impacts of sorption on microbial availability, including equipment, chemicals, and methods.

    (2) Guidance on how to interpret results.

    (3) Guidance for application of predictive techniques. Descriptions of procedures to evaluate ability of microbial processes to overcome sorption limitations.

    (4) Develop technology transfer documents, seminars and laboratory demonstrations to transition the technology to 6.2 level. Where appropriate, supply technology in a form suitable for direct application to 6.3 level.

Relationship to DoD/EPA Environmental Objectives: Information obtained from the performance of this study will contribute to several DoD/EPA environmental remediation objectives. This work will improve contaminant destruction technology by enhancing bioavailability of contaminants sorbed to soil. Specific user requirements that will benefit from performance of this work include:

(1.I.4.c) Decontamination of soils containing energetic materials (A,N,AF)

(1,I.2.i) Contamination under building and roads (A,N,AF)

(1.I.4.n) Remedial treatment technology for soils contaminated with chlorinated and nonchlorinated organics (A,N,AF).

(1.I.1.g.) Treatment systems for water contaminated with Chlorinated and dense hydrocarbons.

(1.I.3.a.) Technologies for the isolation and decontamination of sludge.

(1.I.2.e.) Improved marine sediment remediation technologies for metals, organics and PCBs.

(1.I.4.c.) Decontamination of soils contaminated with energetic materials.

(1.I.1.j) Treatment of Navy relevant contaminants in salt/brackish/groundwater matrices.

(1.I.1.e.) Processes to remediate groundwater contaminated with hydrocarbon fuels.

(1.I.1.n.) Remedial treatment technology for soils contaminated with chlorinated and non-chlorinated organics.

(1.I.2.b.) Dredged sediments area decontamination and reclamation.

(1.I.6.c.) Isolation and treatment technology for contaminated surface water impoundments.

(1.I.2.i) Contamination under building and roads.

(1.I.6.d.) Improved shore and open ocean hazardous material cleanup/restoration.

(2.III.1.d) Enzyme and bacterial treatment technology.

(2.III.2.d) Improved cleanup procedures at locations where UST have leaked.

EXPECTED PAYOFF: Potential Users: DoD, DOE, private Superfund, and Resource Conservation and Recovery Act (RCRA) site managers will benefit from procedures to enhance bioremediation. Development of this technology will allow cost-effective in-situ and landfarming biotreatment of soils and sediments contaminated with explosives and other organic compounds. Current soil incineration techniques destroy local ecosystems. The technology will also benefit ex-situ techniques, such as bioslurry reactor treatment. This will be especially important at those sites where microbial destruction of crystalline TNT is required.

POSITIVE IMPACTS: This study will integrate technology development and basic research to provide better means to develop the most cost-effective treatment options. Rapid determination of factors affecting microbial accessibility to contaminants has the potential to decrease the overall costs of in- situ, landfarming and bioslurry treatment of contaminated soils.

TRANSITION PLAN: This 6.1 level research will directly support bench-scale assessments at the 6.2 level. As work progresses, briefings and direct input by principal investigator will be provided to relevant Environmental Quality and Technology Program 6.2 level biotreatment work units and corresponding work units in the environmental programs of other agencies. In addition, the proposed work will directly support the work developed in the Integrated Biotreatment Research Program SERDP proposal

developed by WES. Technical assistance for these purposes will be available during and after the course of the research. The technology will also be transferred through technical papers, presentations, and work unit reports. Professors, post-doctorals and graduate students will be involved in helping to develop the studies and conduct the work, which will indirectly aid education. We will also consider application of this technology to suitable field scale technologies through use of cooperative research and development agreements (CRADAs).