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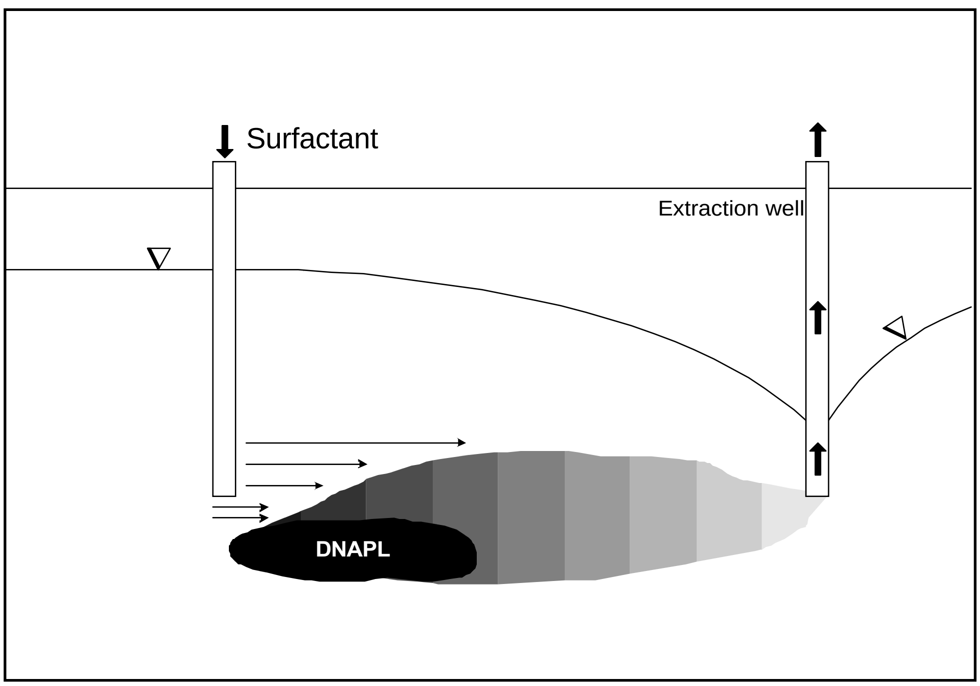
In Situ Remediation Technology Status Report:

Surfactant Enhancements



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U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office
Washington, DC 20460

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Notice

This material has been funded by the United States Environmental Protection Agency under contract number 68-W2-0004. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Foreword

The purpose of this document is to describe recent field demonstrations, commercial applications, and research on technologies that either treat soil and ground water in place or increase the solubility and mobility of contaminants to improve their removal by pump-and-treat remediation. It is hoped that this information will allow more regular consideration of new, less costly, and more effective technologies to address the problems associated with hazardous waste sites and petroleum contamination.

This document is one in a series of reports on demonstrations and applications of in situ treatment technologies. To order other documents in the series, contact the National Center for Environmental Publications and Information at (513) 489-8190 or fax your request to NCEPI at (513) 489-8695. Refer to the document numbers below when ordering.

EPA 542-K-94-003 Surfactant Enhancements
EPA 542-K-94-004 Treatment Walls
EPA 542-K-94-005 Hydrofracturing/Pneumatic Fracturing
EPA 542-K-94-006 Cosolvents
EPA 542-K-94-007 Electrokinetics
EPA 542-K-94-009 Thermal Enhancements

Walter W. Kovalick, Jr., Ph.D.
Director, Technology Innovation Office

Contents

Abbreviations

BTEX = Benzene, Ethylbenzene, Toluene, Xylene
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
DNAPL = Dense Non-Aqueous Phase Liquid
DOE = Department of Energy
PAH = Poly-Aromatic Hydrocarbons
PCE = Tetrachloroethylene
RCRA = Resource Conservation and Recovery Act
SITE = Superfund Innovative Technology Evaluation Program
SVE = Soil Vapor Extraction
SVOC = Semi-Volatile Organic Compound
TCA = 1,1,1-Trichloroethane
TCE = Trichloroethylene
TPH = Total Petroleum Hydrocarbon
VOC = Volatile Organic Compound

Introduction

Purpose and Process

This document describes the development and application of in situ surfactant enhancement as a technology to remove contaminants from soils and ground water at hazardous waste sites. The activities described include research, demonstrations, and field applications of the technology.

Information in this report was found in computerized databases such as the Dialog Information Services, the Environmental Protection Agency's (EPA) Vendor Information System for Innovative Treatment Technologies (VISITT), and EPA's Alternative Treatment Technologies Information Center (ATTIC). Information also came from publications such as EPA's Superfund Innovative Technology Evaluation (SITE) Profiles and the Department of Energy's (DOE) Office of Technology Development Program Reports. This information was supplemented with telephone interviews with representatives of federal agencies, academic research centers, and hazardous waste remediation consulting firms. In some cases, the data concerning the performance of the technology were provided by the technology vendor.

Technology Needs

Treatment of aquifers contaminated by non-aqueous phase liquids (NAPLs) by traditional pump-and-treat systems has proven impracticable. NAPLs have very low solubility in water and tend to exist as pockets at the subsurface location to which they have migrated. They dissolve slowly, leading to very slow rates of removal by pumping. To improve this performance, new technologies are being developed to mobilize or solubilize these pockets to improve removal efficiency.

Technology Description

The application of surfactants can enhance remediation in three ways: by increasing contaminant mobility and solubility to improve pump-and-treat performance; by decreasing the mobility of contaminants to prevent their migration; and to speed the rate of biodegradation of contaminants in soil.

Surfactants increase contaminant removal in two ways. The first is by increasing the apparent solubility of the contaminant in water which improves the mass removal per pore volume. The second is by reducing interfacial tension between the water and the NAPL. This requires greater surfactant concentrations than those required for increasing solubility, but results in direct mobilization of the NAPLs, which may allow them to be extracted more efficiently. However, if uncontrolled, increasing the mobility of the NAPLs also increases the risk of increasing the contaminant plume.

Cationic (positively charged) surfactants have been shown to improve the capacity of soil to sorb hydrophobic organic contaminants, such as polyaromatic hydrocarbons (PAHs). Other research suggests that surfactants may be useful for enhancing in situ biodegradation of hydrophobic pollutants at low surfactant concentrations.

Ongoing or Future Demonstrations and Commercial Applications

DOE Gaseous Diffusion Site, Portsmith, Ohio
INTERA, Inc. and SUNY-Buffalo

Description of Demonstration: If permits can be obtained, this project sponsored by DOE's Morgantown Energy Technology Center will test the efficiency of surfactants for in situ remediation of alluvium contaminated with high levels of DNAPL.

Wastes Treated: Mostly TCE with some PCBs and other chlorinated solvents.

Status: If approved, testing will begin in the summer of 1995. After testing core samples in the laboratory to determine the most effective surfactant, a pre-treatment partitioning tracer test will be performed to determine the "before" volume of NAPL between two existing wells that are currently producing free-phase NAPL. The surfactant flooding then will be conducted with two to three pore volumes of surfactant between these two wells which are 15 feet apart and 20 feet deep. After the surfactant flooding, the partitioning tracer test will be repeated to determine the efficiency of the test volume of surfactant and to calculate the volume needed for complete cleanup. Later, armed with the knowledge from the test, researchers will conduct a full-scale demo at the same site.

Preliminary Results: None yet.

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References:
Jackson, R.E. and Pickens, J.F. *Determining Location and Composition of Liquid Contaminants in Geologic Formations*. U.S Patent No. 5,319,966, 1994.

Technology Development Data Sheet from DOE's Morgantown Energy Technology Center (METC) Report, September 1993.

Wunderlich, R.W.; Fountain, J.C.; Jackson, R.E. "In Situ Remediation of Aquifers Contaminated with Dense Nonaqueous Phase Liquids by Chemically Enhanced Solubilization." *Journal of Soil Contamination* 1(4) 1992, p 361-378.

Hill Air Force Base, Utah
INTERA, Inc., Montgomery Watson Corporation, SUNY-Buffalo

Description of Demonstration: The project will be similar to a test conducted by the State University of New York at the Canadian Forces Base Borden site. The main zone of ground-water contamination is 24 feet deep. Researchers plan to enclose the demonstration zone within a steel cell 30 feet by 30 feet and within this they will place a line of five injection and five extraction wells. The site was a former fire training pit. The Air Force has hired the Montgomery Watson Corporation to do a treatability study for remediation of light non-aqueous phase liquids (LNAPLs) on the base. INTERA is a subcontractor to Montgomery Watson and is responsible for numerical simulation of NAPL solubilization and test hydraulics.

Wastes Treated: BTEX, PCBs

Status: As of July 1994, researchers were doing laboratory work. Field work is scheduled to begin in Summer 1995.

Demonstration Results: None yet.

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References: None yet.

Hill Air Force Base, Utah
University of Oklahoma–Institute for Applied Surfactant Research

Description of Demonstration: The University of Oklahoma is preparing a permit application for the construction of eight 3-meter by 2-meter steel-walled cells to test various in situ technologies. Two cells will be used to test the use of surfactants for solubilization and mobilization. (Other tests will include cosolvent flooding, steam injection, and air injection treatments.) The walls of the test cells are driven several feet into a clay layer that starts about 30 feet below ground level. The saturated zone is 3 to 5 feet thick on top of the clay layer. The sandy, cobble-filled soil has made drilling and retrieving test cores difficult.

Two well configurations are under consideration: (1) four injection wells and three extraction wells at opposite ends of the cell or (2) a single vertical circulation well used for both injection and extraction.

Wastes Treated: LNAPL (a mixture of chlorinated and non-chlorinated VOCs, naphthalene, pesticides, PCBs, dioxins, JP4)

Status: Upon permit approval, construction of the cells will begin. By late summer 1995, some tracer tests will be conducted.

Demonstration Results: None yet.

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References: None yet.

An Operating Facility of a Major U.S. Corporation
GHEA Associates, Inc.

Description of Demonstration: This is a commercial application of an on-site system for cleaning leachates and reconstituting surfactants for an in situ soil flushing remediation project. The project is supported by a New Jersey program to encourage collaboration between New Jersey firms and universities. GHEA Associates has a contract with "a major U.S. corporation" to participate in the cleanup of an industrial site at a working facility. The site is used for machining operations and the soil is contaminated with a mixture of chlorinated organic solvents and BTEX at levels of 1,000 to 2,000 ppm. The water table is about 10 feet from the surface and the soil is very clayey. Researchers will employ slurry walls to isolate the treatment zone and install feed trenches alternated with extraction wells. Because of the limited permeability of the soil, a dense network of feed trenches and extraction wells will be employed. There have not been regulatory barriers at this site. Regulators were satisfied with the installation of monitoring wells.

Wastes Treated: VOCs, SVOCs, BTEX

Status: Some wells were installed, but the project is "on hold" as of April 1995.

Demonstration Results: None yet.

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Gotlieb, I.; Bozzelli, J. W.; Gotlieb, E. "Soil and Water Decontamination by Extraction with Surfactants." *Separation Science and Technology*, 28 (1-3) January-February 1993, p 793-804.

Traverse City Coast Guard Base, Michigan
University of Oklahoma–Institute for Applied Surfactant Research

Description of Demonstration: The primary objective of the field project at the Traverse City Coast Guard Base is to demonstrate the efficiency of surfactant recovery using a novel single well injection/extraction system. Soil at the base is contaminated by PCE, TCE, and BTEX. The secondary objective will be to demonstrate the efficiency of removal of these contaminants from the soil using surfactant flushing. The innovative hydraulic system both injects a surfactant solution and extracts the ground-water/contaminant/surfactant fluid from a single borehole. Simultaneous injection to, and extraction from, a common vertical borehole creates a circulating flow pattern that can be used to capture mobilized contaminants that migrate vertically. The two peripheral wells will serve as monitoring wells and piezometers. The demonstration area will be 10 feet by 10 feet and the depth to ground water is 15 feet. The Dow Chemical Co., a manufacturer of surfactants, has formed a partnership with the investigators to promote the development of this technology. The test will use surfactants having FDA approval for use as indirect food additives. Surfactant and contaminants will be removed and concentrated using micellar-enhanced ultrafiltration and then disposed of by a licensed contractor. The remainder of the effluent will be directed to a carbon treatment system currently in operation at the site.

Wastes Treated: PCE, TCE, BTEX

Status: Site reconnaissance began in September 1994. System installation and conservative tracer tests were completed in October 1994. The demonstration is planned for summer 1995. Data collection and analysis is to be completed by late 1995.

Demonstration Results: None yet.

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Picatinny Arsenal, New Jersey
U.S. Geological Survey and University of Virginia

Description of Demonstration: At Picatinny Arsenal, TCE was used for years as a degreasing solvent and has contaminated a sand and gravel aquifer. The water table is 10 feet below the surface and a lower confining unit 10 to 15 feet thick is another 40 feet from the water table. This project is funded by EPA's Office of Exploratory Research. The site was recently listed as a Superfund site and a pump-and-treat system was installed as an interim remedy.

This is a small-scale field test. Researchers will inject surfactants to cause the desorption of TCE from soil and will monitor the increase of TCE levels in the ground water. The test site is upgradient from the pump-and-treat systems, so surfactant and TCE will be removed there. Three injection wells have been installed perpendicular to the ground-water flow. Three monitoring wells are located downgradient and one monitoring well upgradient from the injection wells. The treatment area is 60 feet by 20 feet. The Picatinny Arsenal was chosen by the U.S. Geological Survey in 1986 as a National Research Site.

Wastes Treated: TCE

Status: Laboratory work has been completed to determine the best surfactant and concentration to use. Wells have been installed and the results of tracer tests confirmed hydraulic control of the test area. Researchers expect to start the demonstration in summer 1995. The demonstration will last four to eight weeks. Data analysis should be complete in late 1995.

University of Virginia researchers have a "preproposal" in to the U.S. EPA's SITE program for doing a project at Picatinny Arsenal in which soils will be flushed with surfactants to make sorbed TCE more amenable to oxygen-enhanced bioremediation.

Demonstration Results: None yet.

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References:

Di Cesare, D. and Smith, J.A. "Effects of Surfactants on the Desorption Rate of Nonionic Organic Compounds from Soil to Water." *Reviews of Environmental Contamination and Toxicology*, 134, 1994, p 1-29.

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Corpus Christi Dupont Site
SUNY Buffalo with Dupont Corporate Remediation Group

Description of Demonstration: A pilot field test for the remediation of an aquifer contaminated with DNAPLs was undertaken at a chlorocarbons manufacturing facility in Corpus Christi, Texas. The site was selected because: it is known to have DNAPLs present in a zone at shallow depths; the contaminated zone has adequate hydraulic conductivity; and the target zone is underlain by a thick clay unit that forms a barrier to further vertical migration. The target zone at this site was a 12 foot sand lens within a thick regional clay unit. It extends from approximately 12 to 24 feet below the ground surface. It is comprised of a very well-sorted fine sand with variable amounts of smectite clays and a low carbon content. The test area was 25 feet by 35 feet.

The process involves adding surfactant to the extracted ground water at the surface, injecting the mixture through an array of distribution wells and withdrawing it through extraction wells. The contaminants are then separated by air stripping and the surfactant solution reinjected. The surfactant used was not a food-grade additive but is approved for use in "food preparation procedures," has low toxicity, and is readily biodegradable under aerobic and anaerobic conditions.

The surfactant flushing system requires only minor modifications of typical pump-and-treat design. The only additional components are mixing and feed tanks for preparation and distribution of the surfactant solution. Ground water is extracted and sent through an air stripper. The stripped solution is then mixed with surfactant to bring the concentration to the desired level (1% for this test) and the solution is then reinjected into the aquifer. The cycle is repeated until the end of the test. The test was conducted in four phases. Phase I (6/91-8/91) used a 1% surfactant solution delivered through a well array consisting of six delivery wells and one central extraction well. Sanding of one extraction well required the installation of a new well for Phase II (3/92-6/92). High sorption of the original surfactant and rapid biofouling of surface tanks and delivery wells resulted in a change of surfactant for Phase III (6/92-10/92). Because of low flow rates due to a depressed regional water table, a smaller area comprising the northern half of the original cell was treated during Phase IV (1/93-2/93).

Wastes Treated: Carbon tetrachloride (CTET)

Status: Completed.

Demonstration Results: Prior to the test, CTET was present at greater than 1,000 ppm in both core and water samples from the test zone. During the test, the average effluent concentration of CTET decreased from 790 ppm during Phase I to 219 ppm in Phase IV. A total of approximately 73 gallons of CTET was removed during the project after 12.5 pore volumes were injected. Analysis of three monitoring well nests within the DNAPLs source zone indicated that DNAPLs were rapidly being removed. By increasing the contaminant solubility with the addition of surfactants, the DNAPLs removal progressed at a rate considerably faster than would be expected with standard pump-and-treat techniques. Researchers also concluded that although surfactant flushing is initially more expensive than standard pump-and-treat, the large reduction in time required to complete the remedial treatment greatly reduces the operating and maintenance costs.

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Fountain, J.C. and Waddell-Sheets, C. "A Pilot Field Test of Surfactant Enhanced Aquifer Remediation: Corpus Christi, Texas." Abstract from presentation at an ACS Symposium in Atlanta, Georgia, September 27-29, 1993.

Fountain, J.C. "A Pilot Scale Test of Surfactant Enhanced Pump and Treat." *Proceedings of Air and Waste Management Association's* 86th Annual Meeting in Denver, Colorado, June 13-18, 1993.

Canadian Air Forces Base Borden, Alliston, Ontario, Canada
State University of New York (SUNY) Buffalo

Description of Demonstration: Researchers conducted a field-scale test of a surfactant flooding system to extract organic pollutants from a sand aquifer. The test was conducted at the Canadian Air Forces Base Borden, a field test facility operated by the University of Waterloo's Centre for Ground-Water Research. A three-square-meter cell was built in a four-meter-thick surficial sand aquifer by driving sheet piling walls into the underlying clay. A second sheet-piling barrier was installed one meter beyond the first wall for secondary containment. Five injection wells were installed on one side of the cell and five extraction wells on the other side. Multi-level monitoring wells also were installed. PCE was introduced into the test cell. The cell was then flushed by pumping a 2% aqueous mixture of surfactant from one side of the cell to the other. On the surface, the contaminant was air stripped and the aqueous surfactant solution recycled.

Wastes Treated: PCE

Status: Completed.

Demonstration Results: Approximately 80% of the PCE that was spilled into the cell was recovered. The results of analyses of the core and monitoring wells, however, suggest that the remaining PCE is not in the cell. Probable explanations include volatilization of PCE from the surface of the cell and, possibly, that some PCE was trapped at the edges of the cell where the zig-zag shape of the sheet piling walls created considerable dead space. The surfactant solution was initially injected into the five injection wells through a constant-head system on each well. The system was changed to a peristaltic pump delivery system due to plugging of the injection wells by fine material.

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References:

Fountain, John C. and Hodge, Dennis. *Project Summary: Extraction of Organic Pollutants Using Enhanced Surfactant Flushing–Initial Field Test (Part 1)*. NY State Center for Hazardous Waste Management, February 1992.

Surfactant Washing Demonstration
General Motors NAO Research & Development Center
Warren, MI

Description of Demonstration: Following laboratory evaluations of a surfactant washing technique, researchers conducted a two-phase field test of an in situ surfactant washing method at a site contaminated with polychlorinated biphenyls (PCBs) and oils. Feasibility studies were also conducted on the use of ultrafiltration to recover surfactant from aqueous waste streams generated from the in situ surfactant washing. The field test site was used to store unused machinery and the contamination is confined to the upper 15 feet of the subsurface fill material. A containment wall of clay and cement was previously installed around the five-acre site. This wall extends to a depth of 60 feet below the surface. A surfactant solution was applied to a test plot 10 feet in diameter and five feet deep. The leachate was collected with a recovery well installed through the center of the plot. The leachate pumped to the surface was biotreated to degrade the oils and surfactant while the PCBs were recovered from the leachate by an activated carbon system. Soil cores from the site showed initial concentrations of up to 6,000 ppm PCBs and 67,000 ppm oils. In separate tests, leachate from the surfactant washing demonstration was collected in a process tank and pumped into a Romicon Model HF-Lab-5 ultrafiltration unit equipped with either of two membranes (XM50 and PM500) to evaluate the recovery of the surfactant from the leachate for possible reuse.

Wastes Treated: PCBs, oils

Status: Completed.

Demonstration Results: About 10% of the initial contaminants (mass) was washed from the test plot after 5.7 pore volume washings during the phase 1 field test. During the phase 2 field test conducted the following year at the same site, an additional 14% of the contaminants was washed from the test plot after 2.3 pore volume washings. The results from the second phase of the field study surpassed the prediction of the long-term performance of this technology based on the phase 1 results and confirmed the technical viability of this process.

The ultrafiltration feasibility studies showed that 46% of the surfactant (mass) was recovered during the field test using the XM50 membrane. The membrane retained 94% and 89% of the PCBs and oils, respectively. The second field test showed that the PM500 membrane recovered 67% of the surfactant and retained more than 90% and 83% of the PCBs and oils, respectively.

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References:

Abdul, A.S. and Gibson, T.L. “Laboratory Studies of Surfactant-Enhanced Washing of Polychlorinated Biphenyls from Sandy Materials.” *Environmental Science and Technology*, 25 (4) 1991, p 665-670.

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Surfactant Remediation of Ground Water
University of Oklahoma–Institute for Applied Surfactant Research

Description of Research: Researchers have been conducting laboratory, bench-, and pilot-scale work in four areas: the use of food-grade additive (edible) surfactants; use of high-performance surfactants; recovery and reuse of surfactants; and improving the hydraulic efficiency of injected solutions. The work on "edible" surfactants–substances that are already approved by the FDA for use as food additives–may be helpful in expediting cleanup processes from a regulatory perspective and has been funded by EPA's R.S. Kerr Environmental Research Laboratory (RSKERL).

Funding for three field demonstrations have been received and are in the planning stage. These demonstrations will be supported by RSKERL, with additional field studies pending with industry, and the Departments of Defense and Energy.

Wastes Treated: VOCs, SVOCs, BTEX, PAHs, PCBs, metals

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Surfactant Enhanced Aquifer Remediation
The University of Michigan

Description of Research: Dr. Abriola's research group has been conducting laboratory and numerical modeling studies to evaluate the use of surfactants for remediating aquifers contaminated by nonaqueous phase liquids (NAPLs). This work has been funded by the EPA's R.S. Kerr Environmental Research Laboratory and Great Lakes Mid-Atlantic Hazardous Substance Research Center (HSRC). The specific objectives of this research are to: screen and select surfactants that will enhance the solubility of NAPLs in water; measure the solubilization of representative NAPLs (e.g., dodecane, PCE, o-DCB) in aqueous surfactant solutions; quantify the ability of selected surfactants to recover entrapped NAPLs from soil columns; and develop and evaluate numerical models capable of predicting surfactant-enhanced solubilization and mobilization of NAPLs in ground-water systems.

Soil column experiments were conducted to test the ability of a nonionic surfactant, polyoxyethylene (20) sorbitan monooleate (trade name Witconol 2722 or Tween 80), to recover entrapped dodecane. After injecting a 4% surfactant solution, the concentration of dodecane exiting the column increased by approximately 100,000 times. Removal of 10% of the residual dodecane required 0.7 liters of surfactant solution, while comparable recovery without surfactant would have required 130,000 L of water. Numerical models were developed to explore the optimal surfactant flushing strategies based on the flow rate, flushing time, and volume of surfactant required to remove NAPLs from soil columns.

Additional studies are underway to investigate the effects of rate-limited solubilization, NAPL mobilization and sorption on surfactant-based remediation technologies. No field demonstrations have been conducted to date, but we anticipate that these studied will provide the basis for such work.

Wastes Treated: VOCs, dodecane

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Recycle/Reuse of Surfactant Used in Flushing
Eckenfelder, Inc.

Description of Research: Researchers from Eckenfelder, Inc., and Vanderbilt University have successfully tested a pilot-scale system for recycle and reuse of spent surfactant solution from organics-contaminated soil washing. The research involved testing of the integrated pilot-scale unit on the removal of biphenyl from a soil test bed (152 pounds) spiked with biphenyl as a representative nonvolatile contaminant and the continued treatment of the soil with the recycled surfactant solution. Not only was 99% of the biphenyl removed from the soil, but there was no decrease in the effectiveness of the recycled surfactant solution in removing the biphenyl compared to the virgin solution.

This work was conducted under a U.S. EPA Small Business Innovative Research Phase II (SBIR-II) research grant. Since it had been determined in earlier Phase I research that the surfactant can remove high levels of biphenyl (1000 mg/kg) from soil, the Phase II research simulates the polishing of the removal of biphenyl. Soil with an initial biphenyl concentration of 92 mg/kg was cleaned to approximately 1 mg/kg using 7.7 pore volumes of a 2.5% surfactant solution. A conservative estimate of 20 to 40 pore volumes of water would be required to reach the same degree of biphenyl removal. The process achieved a 90% volume reduction of waste even without optimization of the system.

Researchers also have developed a mathematical model to assess relative cleanup times as a function of the location of the recovery and injection wells, surfactant concentration, solution flow rates, and soil particle size. The model also has been used to estimate preliminary full-scale costs for PCB removal.

The surfactant selected by Eckenfelder, Inc. for testing is sodium dodecyl sulfate (SDS). It is biodegradable, relatively nontoxic, and commercially available. The anionic character of SDS permits its recovery and reuse by solvent extraction and also reduces its tendency to sorb to negatively charged soils, such as clays.

Researchers have proposals in to DOE and DOD for further tests of both in situ and ex situ systems.

Wastes Treated: PCB-contaminated soil

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Soil-Surfactant Interactions in In Situ Soil Washing
Howard University

Description of Research: Researchers currently are conducting tests on treatment of PCBs with surfactants with the support of the Great Lakes/Mid-Atlantic Hazardous Substance Research Center.

Wastes Treated: PCBs

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Use of Cationic Surfactants to Reduce Mobility of Contaminants
University of Michigan

Description of Research: Researchers with the Great Lakes/Mid-Atlantic Hazardous Substance Research Centers are conducting basic research to determine the partitioning characteristics of PAHs such as phenanthrene. This information applies to the use of cationic surfactants to reduce the mobility of contaminants such as PAHs. Such treatment may be used in conjunction with bioremediation to keep the contaminants from migrating over the relatively long period for complete biodegradation to occur.

Wastes Treated: PAHs

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References:
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Surfactant Enhancement of Biodegradation of Aromatic Hydrocarbons
Cornell University

Description of Research: A study was conducted to determine whether a non-ionic surfactant added to the surface of Lima silt loam would enhance the biodegradation of phenanthrene and biphenyl. Researchers concluded that surfactants at low concentrations may be useful for in situ bioremediation of sites contaminated with hydrophobic pollutants without causing movement of the parent compounds to ground water. Dr. Alexander will continue with this work but has no plans to conduct field studies.

Wastes Treated: PAHs

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Surfactant Enhanced Soil Treatment
Michigan State University

Description of Research: Dr. Boyd is working on three research projects involving surfactants:

<u>Surfactant treatment of soils and sediments</u>
Dr. Boyd is conducting basic research to study the effects of different classes of surfactants on the partitioning of contaminants between the water and solid phases of sediments and sandy soils. Tests have been conducted on DDT, PCBs, and PAHs such as naphthalene and phenanthrene.

<u>Modification of soils with cationic surfactants</u>
Boyd is treating clayey soils with cationic surfactants to make the soil more sorptive to common organic contaminants. Though his work is basic research, a projected use of the technique would be to inject the cationic surfactant into the ground in a location through which a contaminant plume would flow. Theoretically, contaminant concentrations in the water downgradient from the treated (sorptive) zone would be substantially reduced. The contaminants immobilized within the zone could then be treated with enhanced bioremediation to provide a comprehensive in-situ remediation technology. In a related application, the cationic organo-clays could be used as components of barrier walls. They would not only seal an area, but sorb any contaminants threatening to seep through.

<u>Effects of low levels of surfactants on bioremediation</u>
Through a cooperative agreement with ERL-Athens, Boyd has just begun laboratory work to study how the biological dechlorination of PCBs in sediments can be enhanced by treating the sediments with low levels of surfactants.

Wastes Treated: PCBs, PAHs

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