EPA

U.S. Environmental Protection Agency

Office of Solid Waste and Emergency Response

Office of Research and Development

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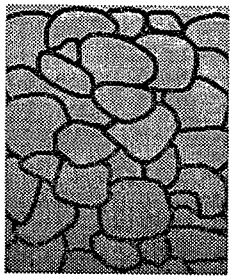
BIOREMEDIATION IN THE FIELD

An information update on applying bioremediation to site cleanup.



Update on the Bioremediation Field Initiative

The Bioremediation Field Initiative was established to provide the U.S. Environmental Protection Agency (EPA) and State Project Managers, consulting engineers, and industry with timely information regarding new developments in the application of bioremediation at hazardous waste sites. The Initiative provides evaluation of the performance of selected full-scale field applications (these sites are discussed on p. 40); provides technical assistance to Remedial Project Managers (RPMs) and On-Scene Coordinators (OSCs) through the Technical Support Centers; and is developing a data base on the field applications of bioremediation, which is summarized in this bulletin (see p. 11).

Eight sites have been selected for field evaluation of bioremediation: Libby Ground Water Superfund site, Libby, Montana; Park City Pipeline, Park City, Kansas; Bendix Corporation/Allied Automotive Superfund site, St. Joseph, Michigan; Eielson Air Force Base Superfund site, Alaska; Hill Air Force Base Superfund site, Utah; Escambia Wood Preserving site–Brookhaven, Brookhaven, Mississippi; Public Service Company, Denver, Colorado; and Reilly Tar and Chemical Corporation Superfund site, St. Louis Park, Minnesota.

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In This Issue

SITE Program Demonstrates Success on Two Bioremediation Projects

The Superfund Innovative Technology Evaluation (SITE) Demonstration Program, which oversees demonstrations of innovative technologies for remediating hazardous wastes, has completed two pilot-scale bioremediation projects. One project was conducted on soils from the Burlington Northern Superfund site in Brainerd, Minnesota, and the other was conducted on ground water at the MacGillis and Gibbs Company site in New Brighton, Minnesota. In both projects, bioreactor treatments were demonstrated to be effective for remediating wood preserving wastes.

The SITE Demonstration Program is one of four major elements of the SITE program, which was established in 1986 by EPA's Office of Research and Development (ORD) to promote the use of innovative remediation technologies at Superfund sites. The other elements of the SITE program are the Emerging Technology Program, Monitoring and Measurement Technologies Program, and Technology Transfer Program. (The Emerging Technology Program will be featured in Issue No. 9 of *Bioremediation in the Field*.) Through the SITE Demonstration Program, EPA enters into cooperative agreements with developers of innovative technologies to conduct demonstrations of these technologies at Superfund sites. The developer usually conducts the actual demonstration; EPA then samples the results and analyzes the data to assess the technology's performance, reliability, and cost.

Bioreactor Treatment of Soils from the Burlington Northern Superfund Site

This project was conducted from May to September 1991 as a joint effort of the SITE program and a project being conducted by the Water and Hazardous Wastes Treatment Research Division of EPA's Risk Reduction Engineering Laboratory to collect information on

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SITE Program Demonstrates Success on Two Bioremediation Projects

(Continued from page 1)

remedial techniques designated as Best Demonstrated Available Technologies (BDATs). The goal of the project was to evaluate the extent to which polynuclear aromatic hydrocarbons (PAHs) could be degraded in a slurry-phase bioreactor system and to assess the air emissions such a system would produce. Testing was conducted at the U.S. EPA Test and Evaluation facility located at the Gest Street Wastewater Treatment Plant in Cincinnati, Ohio.

PAH-contaminated soils from the Burlington Northern Superfund site were treated in five 64-liter, stainless steel, slurry-phase bioreactors. A schematic of one of the reactors is shown in Figure 1. Each reactor was equipped with agitation, aeration, and temperature-control systems. The reactor contents were agitated by a rake mechanism, an airlift circulation system, and a low-shear impeller. Air diffusers on the rake arm shaft near the bottom of the reactor aerated the soil. A heat tape system controlled the reactor temperature and provided a digital temperature readout. Each reactor was inoculated with inorganic nutrients and PAH-degrading microorganisms isolated from the Burlington Northern site. The reactors were operated in parallel to allow a statistical validation of the results of the analyses.

In laboratory testing prior to the demonstration, researchers determined that soils from the Burlington Northern site consisted primarily of sand and that the bioreactors could not keep heavy sands in suspension. For this reason, soils were wet-milled to increase their viscosity and decrease their settling velocity before being fed to the reactors.

Prior to treatment, the soils had a total PAH concentration of 10,973 mg/kg, with a 2- and 3-ringed PAH concentration of 5,892 mg/kg and a 4- and 6-ringed PAH concentration of 5,081 mg/kg. Over the 12-week study, the average reduction in total PAHs for the five reactors was 93.4 percent, with a 97.4 percent reduction in 2- and 3-ringed PAHs and a 90 percent reduction in 4- and 6-ringed PAHs. The lower molecular weight 2- and 3-ringed PAHs also degraded more rapidly than 4- and 6-ringed compounds, reflecting either the preference of bacterial populations for the lower weight compounds or their relative solubility and bioavailability.

Air emissions from the reactors were sampled for total hydrocarbons, semivolatile compounds, and volatile compounds. Total hydrocarbon emissions were highest during the first 1½ days of the study, then rapidly dropped to below background levels. Similarly, emissions of volatile and semivolatile compounds initially were detected, then fell to below detection limits after the first week of the study. Based on these findings, researchers concluded that slurry-phase bioreactors do not require elaborate air emissions control systems unless the soil or ground water to be treated contains very high concentrations of volatile organic compounds.

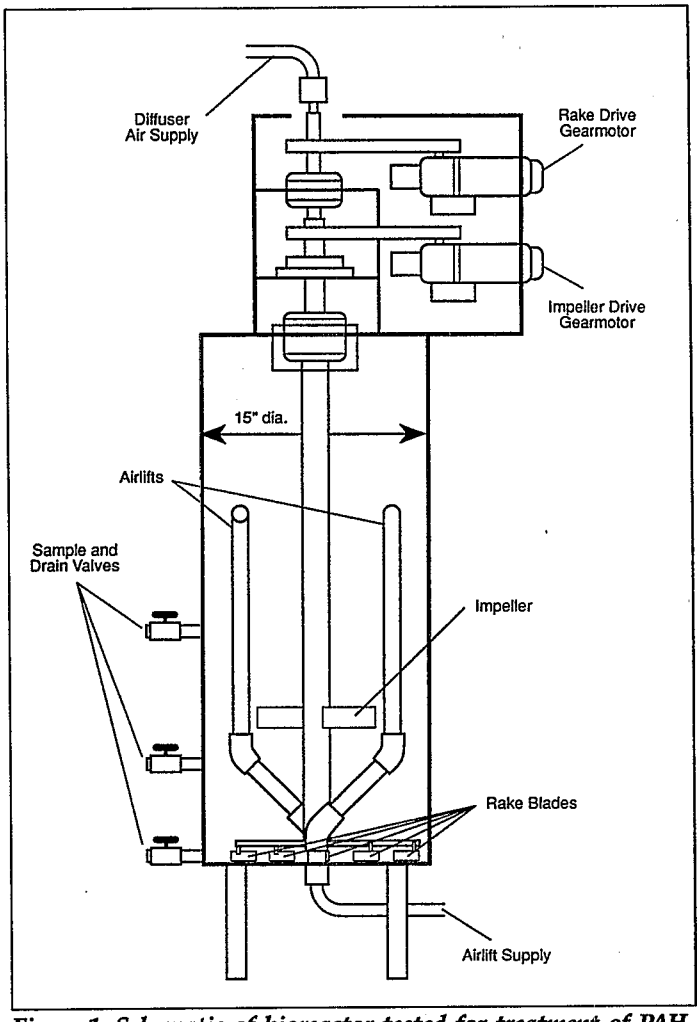


Figure 1. Schematic of bioreactor tested for treatment of PAH-contaminated soils from Burlington Northern Superfund site.

Bioreactor Treatment of Ground Water at MacGillis and Gibbs Company Site

During the 1950s and 1960s, a mixture of pentachlorophenol (PCP) and oil was used for weed control and wood treatment at the MacGillis and Gibbs Company site. Over the years, residues from the weed control application and spills from the wood preserving process leached into ground water beneath the site. A 1984 remedial investigation/feasibility study (RI/FS) indicated that the ground water contained high concentrations of PCP. From July to September 1989, the SITE program conducted a demonstration project at the MacGillis and Gibbs Company site to examine the effectiveness of a multistage, aerobic, fixed-film bioreactor for treatment of the PCP-contaminated ground water.

A schematic of the bioreactor used in the demonstration is shown in Figure 2. Contaminated ground water was pumped from a well at the site into a 100-gallon conditioning tank. From the conditioning tank, water passed through a heat exchanger into the main treatment unit, where it was aerated and contacted the fixed-film biomass. Gaseous emissions from the treatment unit were passed through a carbon adsorption system and released. Treated ground water was filtered to remove solids, passed through a carbon adsorption system, and discharged to the site. The bioreactor was tested in three 2-week stages at 1-, 3-, and 5-gpm flow rates. Flow rates were incrementally increased to allow the reactor to stabilize and provide "steady state" analytical results.

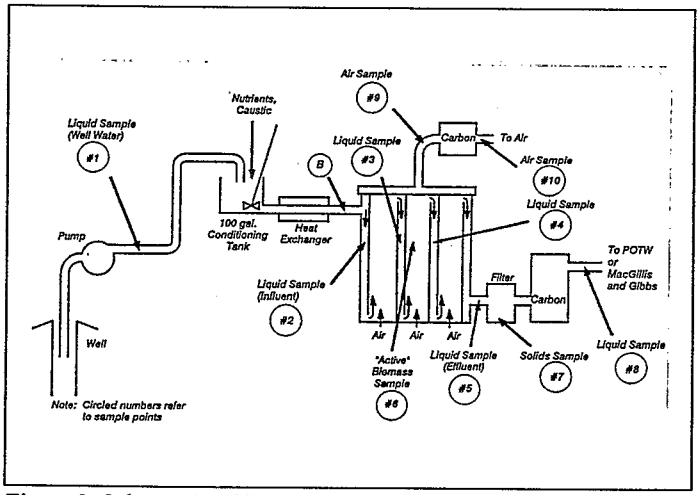


Figure 2. Schematic of bioreactor system tested at MacGillis and Gibbs Company site.

Although there was some uncertainty about the concentration of PCP in the influent, the initial concentration of PCP in the ground water was estimated at 45 mg/L. Based on this figure, the bioreactor was found to achieve a greater than 95 percent PCP removal at the 5-gpm flow rate and a greater than 99 percent PCP removal at the 1- and 3-gpm flow rates. An economic analysis of the demonstration project suggested that the bioreactor system could be operated at other sites for a total capital and operating cost of $2.94 per 1,000 gallons of water treated.

Ongoing SITE Bioremediation Projects

In addition to the recently completed projects described above, several other bioremediation technologies currently are being tested through the SITE Demonstration Program. These include white-rot fungi treatment for PCP-contaminated soils at the Escambia Wood Preserving site in Brookhaven, Mississippi, and bioventing of PAH-contaminated soil at the Reilly Tar and Chemical site in St. Louis Park, Minnesota. An additional study on slurry reactor treatment of PAH-contaminated sediments from the municipal town gas site of the Niagara Mohawk Power Corporation in Utica, New York, will begin in summer of 1993.

For more information, contact Ronald Lewis of the SITE program at 513-569-7856.

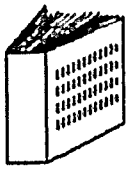
Bioremediation Field Initiative Contacts

Fran Kremer, Ph.D.
Coordinator, Bioremediation Field Initiative
U.S. Environmental Protection Agency
Office of Research and Development
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7346

Nancy Dean
U.S. Environmental Protection Agency
OS-110W
Technology Innovation Office
Office of Solid Waste and Emergency Response
401 M Street, SW.
Washington, DC 20460
703-308-8797

To be added to the mailing list to receive *Bioremediation in the Field*, call 513-569-7562.

This initiative is a cooperative effort among the Technology Innovation Office (TIO), Office of Solid Waste and Emergency Response (OSWER), and the Office of Technology Transfer and Regulatory Support (OTTRS) and Office of Environmental Engineering and Technology Demonstration (OEETD), Office of Research and Development (ORD). Major contributors to this initiative include the waste programs in the EPA Regional Offices and the following laboratories in ORD: Ada, OK; Athens, GA; Cincinnati, OH; Gulf Breeze, FL; and Research Triangle Park, NC.



EPA Issues Final Rules for Corrective Action Management Units and Temporary Units

On February 16, 1993, the U.S. Environmental Protection Agency (EPA) promulgated regulations under Subtitle C of the Resource Conservation and Recovery Act (RCRA) describing two new waste management units that may be used in RCRA corrective actions: (1) corrective action management units (CAMUs), and (2) temporary units (TUs). The purpose of these units is to facilitate remedial activities at RCRA facilities. EPA believes that CAMUs and TUs will increase on-site corrective actions and the use of innovative technologies, such as bioremediation, at RCRA facilities. This flexibility also will help to promote more expeditious cleanups at many facilities. The following article is reprinted from a fact sheet (EPA/530/F-93/001) on the new regulations that was issued by EPA's Office of Solid Waste and Emergency Response (OSWER) in January 1993.

Subtitle C of the 1976 Resource Conservation and Recovery Act (RCRA) created a comprehensive program for the safe management of hazardous wastes. In 1984, Congress passed the Hazardous and Solid Waste Amendments (HSWA), which mandated even stricter standards for the regulation of hazardous wastes. One of the key provisions of HSWA was the authority provided to EPA to compel "corrective action" for environmental problems that have resulted from historical waste management practices at hazardous waste facilities.

Since 1984, corrective action has become a major part of the RCRA program. More than 800 facilities are now in the process of investigating and cleaning up contamination problems. EPA estimates that as many as 4,000 RCRA facilities eventually may need some type of corrective action.

The actual cleanup of these facilities, as with Superfund sites, often involves excavating and managing large volumes of hazardous wastes, including contaminated soils, debris, sludges, and other wastes. These cleanup wastes are subject to the same set of RCRA regulations that apply to management of newly generated hazardous wastes. EPA's experience, however, with implementing the corrective action program has shown that application of these uniform, national standards often has been counterproductive when applied to the cleanup of individual sites. In many cases, the application of these standards, such as the RCRA land disposal restrictions (LDRs), has forced EPA to select remedies that are environmentally less effective and reliable, and in some cases more expensive, than alternative remedies that could otherwise have been available. For example, treatment standards requiring incineration often preclude the use of other effective treatment technologies that could be used in achieving a protective cleanup for a site.

In order to address these problems, EPA has finalized regulations that provide for the use of corrective action management units (CAMUs) when cleaning up sites under RCRA and Superfund. Use of the CAMU concept under these regulations will ensure cleanups that are fully protective, yet better tailored to actual site conditions. Under the rule, appropriate treatment requirements will be determined as part of the overall cleanup plan for a particular site. This is expected to result in more expeditious cleanups and will promote the use of new, innovative treatment technologies. The use of CAMUs should decrease the volumes of cleanup wastes that must be incinerated and increase the use of alternative treatment technologies that are appropriate for actual site and waste characteristics. In addition, EPA expects the new rule to result in less waste being hauled off site and, overall, more treatment of greater volumes of cleanup wastes.

The CAMU regulations contain important restrictions and safeguards that ensure the rule will be used to achieve more protective and effective cleanups. For example, newly generated process wastes cannot be managed in CAMUs, nor can wastes that originate from other cleanup sites. Technical requirements for ground water monitoring, closure, and postclosure also are specified. In addition, the rule requires thorough public review and comment on CAMU decisions.

Based on the Regulatory Impact Analysis conducted for this rule, the use of the CAMU concept also is expected to result in billions of dollars of cost savings for industry and federal agencies.

In addition to the CAMU provisions, the final rule also will allow regulatory agencies to approve "temporary units" (TUs) for remedial purposes. This provision will allow regulatory agencies to modify design standards for tanks and container storage units that are used for short-term treatment or management of remediation wastes.

These rules took effect April 19, 1993, in states where EPA is implementing the RCRA corrective action program. In other states, the rules will not take effect until they are adopted by the state legislatures. Since the rule is considered "less stringent," adopting the

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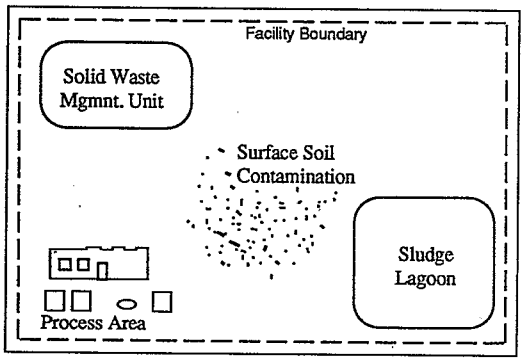
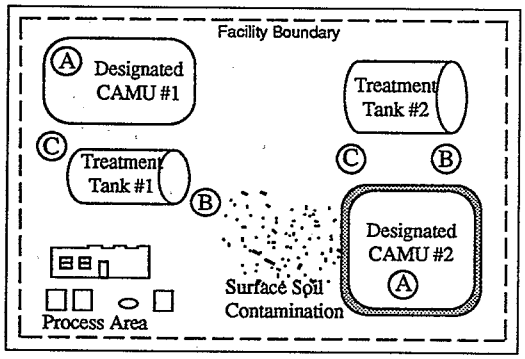
Example 1



Before Remedial Activities

The remedial goal at this facility is (1) to treat and contain contaminated surface soil from the site, and (2) to stabilize and contain sludge wastes from the leaking sludge lagoon. In this case, the two waste streams have very different characteristics and require different treatment processes. In addition, they will require different ultimate containment methods.



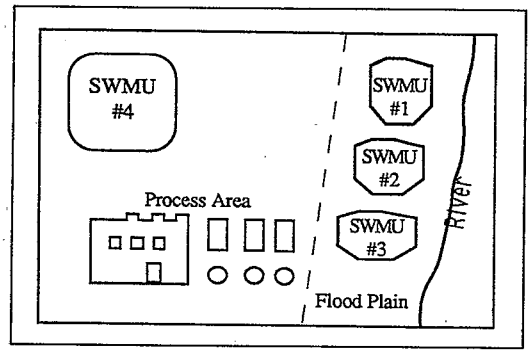
After Designating CAMUs

(A) To allow for these differing waste characteristics and to minimize further contamination, the regulatory officials have designated two separate CAMUs to deal with the two remediation waste streams.

(B) Remediation wastes from the contaminated surface soil of the facility will be treated in treatment unit #1 and remediation wastes from the lagoon will be treated in treatment unit #2. Both units may be temporary units authorized specifically for the remediation process.

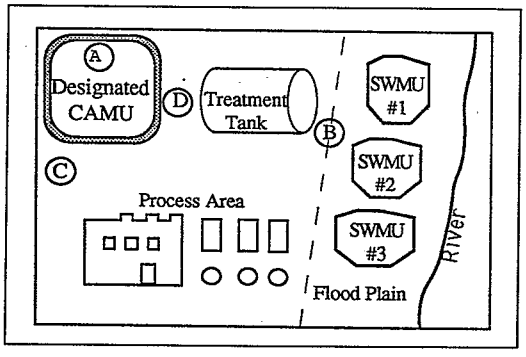
(C) Treatment residuals can be placed in each CAMU without triggering the RCRA land disposal restrictions (LDRs). Each CAMU must be protective of human health and the environment. For the sludge lagoon (now CAMU #2), this may mean retrofitting the unit, even though it would not necessarily need to meet minimum technology requirements (MTRs).

Example 2



Before Remedial Activities

The remedial goal at this facility is to treat the wastes in each of the solid waste management units (SWMUs) and to consolidate the wastes from the SWMUs in the flood plain to a more protective location.



Resolution Using CAMUs

(A) The Regional Administrator or State Director designates SWMU #4 as a CAMU.

(B) The remediation wastes from the four SWMUs then are removed and treated in an onsite temporary treatment unit.

(C) SWMU #4 is retrofitted with a liner.

(D) The treatment residuals can be placed in the CAMU without meeting the RCRA land disposal restrictions (LDRs). Specific treatment standards and other design, operation, closure, and postclosure requirements for the CAMU would be specified according to the criteria in the CAMU regulations.

EPA Issues Final Rules for Corrective Action Management Units and Temporary Units

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CAMU rules will not be mandatory. EPA, however, strongly encourages states to adopt these regulations.

For additional information or to order a copy of the *Federal Register* notice, contact the RCRA Hotline, Monday to Friday, 8:30 AM to 7:30 PM EST. The national, toll-free number is 800-424-9346; TDD 800-553-7672 (hearing impaired); in the Washington, DC metro area, the number is 703-412-9810, or TDD 703-412-3323. The general public also may obtain copies of documents applicable to this rulemaking by writing to the RCRA Information Center (RIC), U.S. Environmental Protection Agency, 401 M Street, SW., Washington, DC 20460.

Glossary and Acronyms

Corrective action management unit (CAMU): An area within a facility that is designated for the management of remediation wastes generated during the implementation of specific corrective action requirements. CAMUs can be designated only by the EPA Regional Administrator.

Temporary unit (TU): Temporary tanks and/or container storage areas used solely for treatment or storage of hazardous remediation wastes during specific remediation activities. Designated by the Regional Administrator, such units must conform to specific standards and may be in operation only for a prespecified period of time.

Remediation wastes: All solid and hazardous wastes, and all media (including ground water, surface water, soils, and sediments) and debris that contain listed hazardous wastes or that themselves exhibit a characteristic, that are managed for the purpose of implementing corrective action requirements.

Land disposal restrictions (LDRs): A series of regulations restricting the land disposal (placement in or on land) of hazardous wastes as mandated by the 1984 HSWA amendments.

In situ: In place.

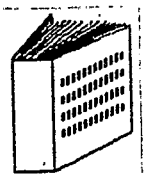
RCRA: The Resource Conservation and Recovery Act, enacted in 1976.

HSWA: The *Hazardous and Solid Waste Amendments*, enacted in 1984.

TSDF: Treatment, storage, and disposal facility.

RFA: RCRA facility assessment.

MTRs: Minimum technology requirements.



EPA Signs License Agreement for TCE-Degrading Microorganisms

On March 8, 1993, the U.S. Environmental Protection Agency (EPA) signed a nonexclusive agreement with SBP Technologies, Inc. (SBP) to license to SBP the patent for *Pseudomonas cepacia* G4 (G4) and the patent application for *Pseudomonas cepacia* G4 5223 PR1 (PR1). These recently isolated microorganisms degrade chlorinated aromatic and chlorinated aliphatic compounds, such as trichloroethylene (TCE), under aerobic conditions. G4 and PR1 are particularly valuable because, unlike other TCE-degrading microorganisms, they destroy TCE without generating byproducts, such as vinyl chloride, that can be more hazardous than TCE itself. Under the March 8 agreement, EPA also licensed to SBP the patent for the general oxygenase enzyme-mediated pathway by which G4 and PR1 effect the degradation of TCE. This patent covers any mutated or genetically engineered microorganism that uses the same pathway to degrade chlorinated aromatic and chlorinated aliphatic compounds.

PR1, which is a genetically altered derivative of G4, may be more acceptable than G4 for environmental cleanups. Unlike G4, PR1 does not require an inducer chemical, such as toluene or phenol, to activate the genes that produce TCE-degrading oxygenase enzymes. Researchers obtained the PR1 mutant by applying the mobile genetic transposon Tn5. In nature, Tn5 exists by inserting itself onto the chromosomes of microorganisms, sometimes causing a "break" in a gene or in a gene regulator that activates or deactivates a particular set of genes. In PR1, Tn5 apparently inserted itself into a genetic element involved in regulating the production of toluene ortho-monooxygenase (tomA), which is the principal enzyme required for TCE degradation.

A drawback to PR1 is that the strain requires a secondary nutrient source for growth, because TCE alone is not sufficient. SBP currently is investigating the use of slow-release, microencapsulated nutrients and oxygen to sustain long-term activity of PR1.

SBP licensed the patents for several commercial applications of PR1 and has been working with the University of West Florida Center for Environmental Diagnostics and Bioremediation (CEDB) and the University of Waterloo Centre for Groundwater Research to develop innovative application strategies. Two strategies using PR1 have been tested at bench scale, and pilot-scale applications of these strategies

are scheduled for summer of 1993. In one application, PR1 will be used in an aboveground, contained bioreactor to degrade vapor-phase TCE from an air-stripping, pump-and-treat operation. If successful, this bioreactor may replace or supplement the carbon filtration system currently being used. In a second application, a funnel-and-gate/removable cassette system will be used for in situ PR1 treatment of a flowing, TCE-contaminated, ground water stream. If successful, this in situ system will replace or supplement the current pump-and-treat system, which is costly and slow.

In association with CEDB and the EPA's Environmental Research Laboratory at Gulf Breeze, Florida, SBP recently submitted permit applications for a second strain of G4, *Pseudomonas cepacia* GM-5223-PHE1, also capable of degrading chlorinated aliphatics and aromatics.

For more information, contact Dr. Parmley Pritchard of the U.S. EPA Gulf Breeze, Florida, Environmental Research Laboratory at 904-934-9260.

Bioremediation Action Committee Announces Current Activities

EPA's Bioremediation Action Committee (BAC) is sponsoring an EPA/Industry Meeting on Environmental Applications of Biotechnology, the third such meeting to take place since the BAC was formed in 1990. The theme of the meeting, which is scheduled to be held June 15-16, 1993, in Crystal City, Virginia, is the development of partnerships. On the first day, representatives of industry, states, academia, and nongovernmental institutions will present their views on opportunities for partnerships to advance bioremediation. EPA Administrator Carol Browner has been invited to participate as the featured speaker. On the second day, the BAC subcommittees will discuss their progress, and discussion sessions will be held to identify priorities for the future.

Now in its third year, the BAC is a partnership of experts from government, industry, academia, and the public dedicated to expanding the nation's use of bioremediation. The BAC was established with three broad goals: (1) to develop a national bioremediation response capability for oil spills, (2) to develop effective biological treatments for hazardous waste cleanup, and (3) to develop the potential for biotechnology to prevent or reduce pollution. To further these goals, the BAC has subcommittees focusing in the following areas:

- *Communications.* The BAC's communications subcommittee actively promotes the increased acceptance and use of bioremediation by providing information on the latest advances in biotechnology and the accomplishments of the BAC to both the technical and nontechnical communities.
- *Data and information.* This subcommittee is responsible for collecting performance and cost data from applications of bioremediation and compiling this information in EPA's Alternative Treatment Technology Information Clearinghouse (ATTIC) data base.
- *Protocols.* This subcommittee develops protocols for testing the applicability, effectiveness, and safety of bioremediation and assists decision-makers in evaluating bioremediation products and applications.
- *Spill response.* The spill response subcommittee collaborates with national and regional response teams to incorporate bioremediation into oil and hazardous substance spill contingency response plans across the United States.
- *Education.* The BAC's education subcommittee is responsible for reviewing existing approaches to bioremediation education and working with academic experts in biology, chemistry, and engineering to develop integrated bioremediation curricula.
- *Research.* The research subcommittee reviews the results of existing research for consistency and overlap and identifies priorities for future bioremediation-related research.
- *Pollution prevention.* The BAC's pollution prevention subcommittee works closely with industry to promote the use of biotechnologies that reduce or eliminate toxic wastes generated by industrial processes.

In addition to the efforts of the subcommittees, the BAC is involved in two EPA-affiliated activities:

- *Regulation and permitting issues.* The BAC serves as a forum for exchange of information between

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EPA Bioremediation Publications

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Overview Documents

Alaskan Oil Spill Bioremediation Project . . . NTIS PB90-216466
A Study to Determine the Feasibility of Using a Ground Penetrating Radar . . . NTIS PB92-169382
Available Models for Estimating Emissions Resulting from Bioremediation Processes: A Review . . . NTIS PB90-228610
Bioremediation of Hazardous Waste . . . EPA/600/R-92/126
Characterizing Heterogeneous Wastes . . . NTIS PB92-216894
Fundamentals of Ground-Water Modeling . . . NTIS PB92-232354
Movement of Bacteria through Soil and Aquifer Sand . . . NTIS PB91-164277
Oil Spill Cleanup . . . NTIS PB92-110469
Reductive Dehalogenation: A Subsurface Bioremediation Process . . . NTIS PB91-144873
Understanding Bioremediation: A Guidebook for Citizens . . . EPA/540/2-91/002

Guidance/Workshops

Methodologies for Evaluating In Situ Bioremediation of Chlorinated Solvents . . . NTIS PB92-146943

Study/Test Results

Action of a Fluoranthene-Utilizing Bacterial Community on Polycyclic Aromatic Hydrocarbon Components of Creosote . . . NTIS PB90-245721
Alternative Biological Treatment Processes for Remediation of Creosote-Contaminated Materials: Bench-Scale Treatability Studies . . . NTIS PB91-179085
Anaerobic In Situ Treatment of Chlorinated Ethenes . . . NTIS PB91-137067
Applications Analysis Report: Biological Treatment of Wood Preserving Site Ground Water by Biotrol, Inc. . . . NTIS PB91-227983
Approach to Bioremediation of Contaminated Soil . . . NTIS PB91-116152
Assessing Detoxification and Degradation of Wood Preserving and Petroleum Wastes in Contaminated Soil . . . NTIS PB90-245275
Bioremediation Case Study Collection: 1991 Augmentation of the Alternative Treatment Technology Information Center (ATTIC) . . . EPA/600/R-92/043
Bioremediation of Contaminated Surface Soil . . . NTIS PB90-164047
Comparison of Methods to Determine Oxygen Demand for Bioremediation of a Fuel-Contaminated Aquifer . . . NTIS PB89-207351
Creosote-Contaminated Sites . . . NTIS PB90-129552
Enhanced Bioremediation Utilizing Hydrogen Peroxide as a Supplemental Source of Oxygen: A Laboratory and Field Study . . . NTIS PB90-183435
Microbial Decomposition of Chlorinated Aromatic Compounds . . . EPA/600/2-86/090
Microbial Removal of Halogenated Methanes, Ethanes, and Ethylenes in an Aerobic Soil Exposed to Methane (Journal Version) . . . NTIS PB89-103196
Nitrate for Biorestoration of an Aquifer Contaminated with Jet Fuel . . . NTIS PB91-164285
Removal of Volatile Aliphatic Hydrocarbons in a Soil Bioreactor . . . NTIS PB88-180393
Role of Microorganisms in the Bioremediation of the Oil Spill in Prince William Sound, Alaska . . . NTIS PB90-263070
Sequential Reductive Dehalogenation of Chloranilines by Microorganisms from a Methanogenic Aquifer . . . NTIS PB90-117219
TCE Removal from Contaminated Soil and Ground Water . . . EPA/540/S-92/002
Technology Evaluation Report: Biological Treatment of Wood Preserving Site Ground Water by Biotrol, Inc. . . . NTIS PB92-110048
Transformation of Halogenated Aliphatic Compounds . . . NTIS PB88-170568

Test Designs/Protocols

Effect of Sodium Chloride on Transport of Bacteria in a Saturated Aquifer Material . . . NTIS PB92-110428
Field Evaluation of In Situ Biodegradation for Aquifer Restoration . . . NTIS PB88-130257
Guide for Conducting Treatability Studies under CERCLA, Aerobic Biodegradation Remedy Screenings . . . NTIS PB92-109065
In Situ Bioremediation of Contaminated Ground Water . . . EPA/540/S-92/003
In Situ Bioremediation of Spills from Underground Storage Tanks: New Approaches for Site Characterization, Project Design, and Evaluation of Performance . . . NTIS PB89-219976
Interactive Simulation of the Fate of Hazardous Chemicals during Land Treatment of Oily Wastes: Ritz User's Guide . . . NTIS PB88-195540
Laboratory Studies Evaluating the Enhanced Biodegradation of Weathered Crude Oil Components through the Application of Nutrients . . . NTIS PB90-264011
Protocol for Testing Bioremediation Products against Weathered Alaskan Crude Oil . . . NTIS PB91-137018
Selection of Nutrients to Enhance Biodegradation for the Remediation of Oil Spilled on Beaches . . . NTIS PB91-233304
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Issue #	Publication #	Issue #	Publication #
1	Out of stock – NTIS PB91-228023	5	EPA/540/N-92/001
2	EPA/540/2-91/007	6	EPA/540/N-92/002
3	EPA/540/2-91/018	7	EPA/540/N-92/004
4	EPA/540/2-91/027	8	EPA/540/N-93/001

Bioremediation Action Committee Announces Current Activities

(Continued from page 7)

EPA personnel and those interested in bioremediation-related regulatory and permitting issues.

- *Bioremediation Field Initiative.* The Bioremediation Field Initiative is an EPA program that monitors and documents the performance of full-scale bioremediation field applications.

The BAC's recent accomplishments include:

- Publishing "Bioremediation Case Studies," a compendium of private sector bioremediation activities.
- Sponsoring a workshop with EPA and state environmental agency officials, and petroleum industry representatives to discuss the use of bioremediation for underground storage tank and other petroleum-contaminated site cleanups.
- Convening a 2-day meeting between industry and academia to discuss bioremediation education interfaces and identify the knowledge, skills, and abilities needed at different educational levels.
- Identifying pollution prevention case studies on the biological destruction of methylene chloride and phenolics in a production process to prevent releases.

For general information on BAC activities, contact Kurt Jakobson at 202-260-0594. The contacts for specific BAC subcommittees and EPA-affiliated activities are listed in the box below.

BAC Contacts

General Information
Mr. Kurt Jakobson, EPA/ORD, 202-260-0594
BAC Executive Director
Mr. Stephen Lingle, EPA/ORD, 202-260-4073
Regulatory/Permitting Issues
Dr. Walter Kovalick, EPA/OSWER, 703-308-8800
Ms. Elizabeth Milewski, EPA/OPPTS, 202-260-6900
Bioremediation Field Initiative
Dr. Fran Kremer, EPA/ORD, 513-569-7346
Ms. Nancy Dean, EPA/OSWER, 703-308-8797
Communications
Dr. Fran Kremer, EPA/ORD, 513-569-7346
Data and Information
Mr. James Solyst, National Governors' Association, 202-624-7739
Protocols
Dr. Edgar Berkey, NETAC, 412-826-5511
Spill Response
Mr. Stephen Luftig, EPA/OSWER, 202-260-2180
Education
Dr. Rashalee Levine, DOE, 301-903-7920
Research
Dr. Martin Alexander, Cornell University, 607-255-1717
Pollution Prevention
Dr. George Pierce, American Cyanamid, 908-862-6000, ext. 415
Dr. Laura Meagher, Rutgers University, 908-932-6571
ATTIC Systems Operator
301-670-6294

Bioremediation Field Initiative Data Base Adds 29 New Sites

The number of hazardous waste sites being tracked by the Bioremediation Field Initiative rose from 130 to 159 in the period from June 1992 to April 1993. Many of the new sites are Air Force bases undertaking bioventing projects on petroleum-contaminated soils as part of the Air Force Bioventing Initiative (see related article, *Bioremediation in the Field*, Issue No. 7, p. 3). Accordingly, the proportion of sites at which soil is being treated also increased during the same time period. Soil remains the most frequently bioremediated medium, present at 111 sites in the Bioremediation Field Initiative's data base (see Figure 1). Ground water is second, undergoing bioremediation at 58 sites. Sediments and sludge are third and fourth with 15 and 10 sites, respectively. At many sites, bioremediation is being conducted or has been completed on more than one medium.

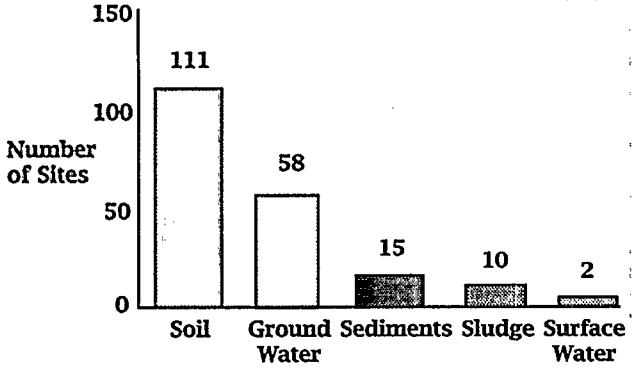

Figure 1. Number of sites treating each medium.

Figure 2 shows the major categories of waste undergoing bioremediation at sites in the data base. Petroleum narrowly edged out wood preserving wastes as the target contaminant at the greatest number of sites. Of the 159 sites in the data base, petroleum products are being treated at 55, wood preserving wastes at 47, solvents at 37, and pesticides at 15. At 11 sites, other wastes, such as polychlorinated biphenyls (PCBs) and munitions residues, are being treated.

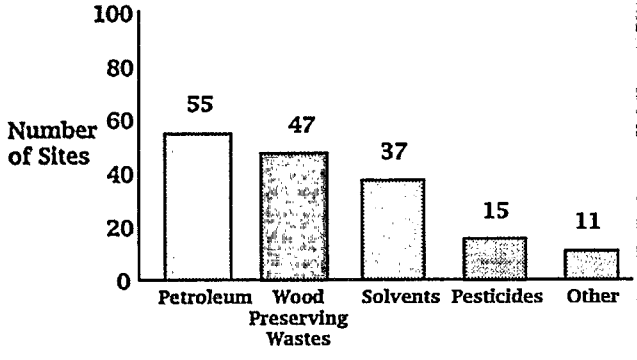

Figure 2. Breakdown of sites by type of contamination.

Most of the sites in the data base have not yet begun full-scale operation (see Figure 3). Over 90 sites still are undergoing laboratory- and pilot-scale treatability studies in the predesign and design phases. Full-scale equipment currently is being installed at a small number of sites. Of the remaining sites, 36 are operating at full scale, and 24 have completed bioremediation activities.

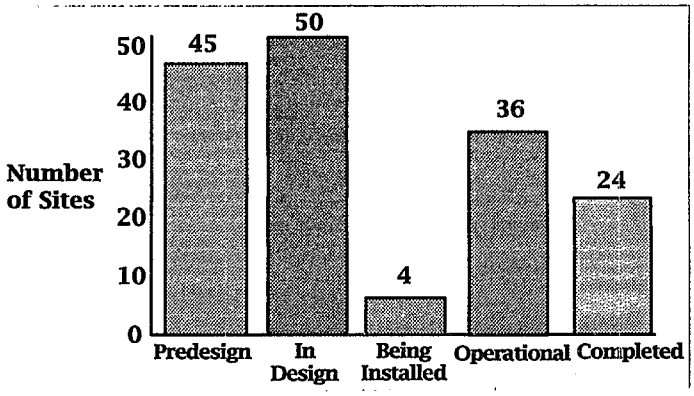

Figure 3. Breakdown of sites by stage of operation.

The sites in the data base are widespread geographically and represent all 10 EPA Regions (see Figure 4). Almost 40 percent of the sites, however, are located in Regions 5 and 9.

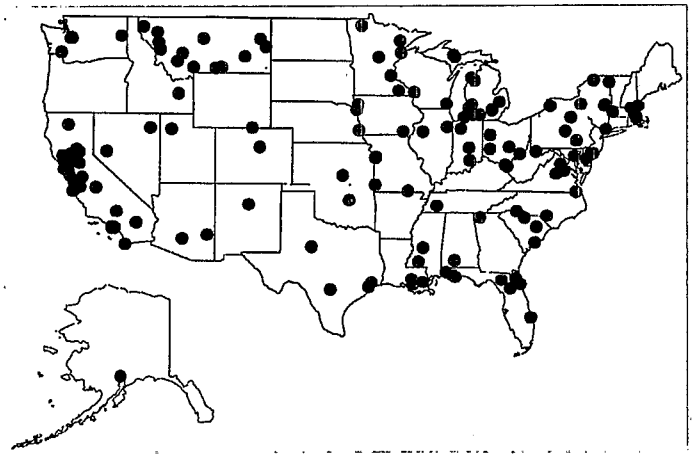

Figure 4. Map showing geographic distribution of sites.

The Bioremediation Field Initiative is continually looking to expand its data base of sites where bioremediation is being considered, planned, or implemented, or has been completed. If you can provide information about bioremediation sites other than those already listed in the *Field Applications of Bioremediation* table on p. 11, please call Ivan Rudnicki at 617-674-7341.

FIELD APPLICATIONS OF BIOREMEDIATION[1]

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
I	Baird and McGuire** Holbrook, MA CERCLA Fund Lead	David Lederer (617)573-5738 Martin Horne (617)292-5716	Ground water: petroleum, wood preserving, pesticides (chlordane), arsenic, lead. Volume: 300 gallons per minute.	Full-scale remediation has been under way since 01/93. Incurred cost: capital, $13M. Cost per year: O&M, $2M.	Ground water: MCLs.	Ex situ treatment, activated sludge, continuous flow. Aerobic conditions, exogenous organisms. Other technologies: chemical treatment for ground water and incineration for soil. 100% of site under bioremediation.	None.
I	Charlestown Navy Yard Boston, MA CERCLA State Lead	Stephen Carlson (617)242-5680	Sediments: wood preserving (PAHs).	Full-scale remediation is planned. Currently in design. Laboratory-scale and pilot-scale studies are being conducted.	Not yet established.	In situ treatment. Ex situ treatment, attached growth process. Aerobic and anaerobic conditions.	None.
I	Coakley Landfill North Hampton, NH CERCLA Enforcement Lead	Steve Calder (617)573-9626 Dan Coughlin (617)573-9620	Ground water: ammonia.	Full-scale remediation is planned. Currently in predesign. Expected start 01/94.	Ground water: NPDES requirements.	Ex situ treatment, typical wastewater system. Other technologies: metal precipitation and air stripping. 50% of site will undergo bioremediation.	None.
I	General Electric** Pittsfield, MA RCRA Lead (Federal)	Joan Blake (202)260-6236	Sediments: PCBs. Volume: 12 cubic meters.	Full-scale bioremediation is not planned. Laboratory-scale studies are planned.	Sediments: PCBs, 2 ppm.	Ex situ treatment, sequencing batch reactor, batch flow. Anaerobic conditions, indigenous organisms. Other technologies: incineration, flotation separation.	None.
I	General Electric—Woods Pond Pittsfield, MA RCRA Lead (Federal)	Joan Blake (202)260-6236	Sediments: PCBs. Volume: 250 gallons.	Full-scale bioremediation is not planned. Laboratory-scale studies are being conducted.	Sediments: PCBs, 2 ppm.	In situ treatment, confined treatment facility, nutrient addition. Anaerobic conditions, indigenous organisms. Other technologies: incineration, flotation separation.	None.
I	Iron Horse Park** Billerica, MA CERCLA Enforcement Lead	Don McElroy (617)223-5571	Sludge / soil (vadose: sand, loam): PAHs, petroleum, lead. Volume: 20K cubic yards.	Full-scale remediation has been under way since 05/92. Total expected cost: $2M.	Soil (vadose): PAHs, 1 mg/kg; TPH, 100 mg/kg (risk-based). Sludge: PAHs, 1 ppm; TPH, 100 ppm (risk-based).	Ex situ land treatment. Aerobic conditions, indigenous organisms. 20% of site under bioremediation.	Cold weather creates short season.

[1] CERCLA/RCRA/UST sites considering, planning, operating, or having used bioremediation.

* Indicates a new site.
** Indicates that the site has been updated.

Shading indicates a non-CERCLA site.

FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
I	Sylvester** Nashua, NH CERCLA State Lead	Chet Janowski (617)573-9623 Paul Hiertzler (603)882-3631	Ground water: solvents (vinyl chloride, benzene, chloroform, MEK, PCE, phenols, TCE, 1,1,2-trichloroethane, chlorobenzene, methylene chloride, toluene, 1,1-dichloroethane, trans-1,2-dichloroethane, 1,1,1-trichloroethane, methyl methacrylate), selenium. Volume: 100 gallons per minute.	Full-scale remediation has been under way since 06/86. Expected completion 07/94. Incurred cost: $15M. Total expected cost: $20M. Cost per year: $2M.	Ground water: vinyl chloride, 95 ppb; benzene, 340 ppb; chloroform, 1,505 ppb; MEK, 8,000 ppb; PCE, 57 ppb; phenols, 400 ppb; TCE, 1,500 ppb; 1,1,2-trichloroethane, 1.7 ppb; chlorobenzene, 110 ppb; methylene chloride, 12.3K ppb; toluene, 2,900 ppb; 1,1-dichloroethane, 1.5 ppb; trans-1,2-dichloroethane, 1,800 ppb; 1,1,1-trichloroethane, 200 ppb; methyl methacrylate, 350 ppb (New Hampshire Drinking Water Standards).	Ex situ treatment, activated sludge, extended aeration, continuous flow. Aerobic conditions. Other technologies: vacuum extraction. 20% of site under bioremediation.	Problems providing nutrients to maintain an active biomass.
II	American Linen Stillwater, NY CERCLA State Lead	Frank Peduto (518)457-2462	Soil: PAHs, VOCs, petroleum (lube oil). Volume: 4,375 cubic yards.	Full-scale remediation was completed 08/92. Started 07/91.	Soil: TCLP to meet soil guidance levels.	Ex situ land treatment. Aerobic conditions, indigenous organisms. 100% of site underwent bioremediation.	Contaminated soil was applied in 2-ft layers; nutrients were added and soil was tilled by mechanical means.
II	FAA Technical Center—Area D** Atlantic County, NJ CERCLA Enforcement Lead	Carla Struble (212)264-4595 Joseph Freudenberg (609)633-1455 Keith Buch (609)484-6644	Soil (saturated sand) / ground water: petroleum (jet fuel, NAPLs). Volume: 33K cubic yards.	Pilot-scale studies were completed 08/92. Total expected costs: capital, $286K; O&M, $200K.	Soil (saturated): New Jersey Soil Action Levels. Ground water: New Jersey MCLs.	In situ treatment, nutrient addition (soil, water), reinjection of ground water. Other technologies: free product extraction, cement kiln incineration, soil venting, off-gas treatment with catalytic incinerator combustion or activated carbon adsorption of VOCs.	None.
II	General Electric—Hudson River NY TSCA Lead (Federal)	Jim Harrington (518)457-3957 Ajay Schroff (518)457-3957	Sediments: PCBs, cadmium, chromium, lead. Volume: 150 cubic feet.	Full-scale bioremediation is not planned. Laboratory-scale studies have been completed. Incurred cost: $2.6M.	Not yet established.	In situ treatment. Aerobic conditions, indigenous organisms. Less than 1% of site underwent bioremediation.	None.
II	General Motors—Central Foundry Division Massena, NY CERCLA Enforcement Lead	Lisa Carson (212)264-6857	Sediments / sludge / soil: HAHs (PCBs). Volume: 350K cubic yards.	Laboratory-scale studies have been under way since 04/93.	Soil: PCBs, 10 mg/kg (risk-based). Sludge: PCBs, 10 ppm (risk-based). Sediments: PCBs, 1 ppm (risk-based).	Ex situ treatment, slurry reactor, batch flow. Aerobic conditions, indigenous organisms. Other technologies: chemical extraction, chemical treatment, thermal desorption.	Oil and grease in samples is hindering efficiency of bioremediation; material may require pretreatment. Will be doing treatability studies of several other technologies in case bioremediation is not successful.
II	Knispel Construction Site Horseheads, NJ UST Lead (State)	Frank Peduto (518)457-2462	Soil / ground water: petroleum.	Full-scale remediation was completed 10/89. Started 01/89. Incurred cost: O&M, $250K.	Soil: petroleum, 5 µg/kg (drinking water standards). Ground water: petroleum, 5 ppb (drinking water standards).	In situ land treatment, hydrogen peroxide, nutrient addition (water). Aerobic conditions, indigenous organisms. 100% of site underwent bioremediation.	None.

* Indicates a new site.
** Indicates that the site has been updated.

Shading indicates a non-CERCLA site.

FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
II	Mobil Terminal** Buffalo, NY CERCLA Enforcement Lead	Robert Leary (716)851-7220 Sal Calandra (716)851-7220	Soil (silt, fill): petroleum (gas and diesel), lead. Volume: 15K cubic yards.	Full-scale remediation has been under way since 07/91.	Soil: NYDEC guidance values based on TCLP.	Ex situ land treatment. Aerobic conditions, exogenous organisms. Other technologies: vacuum extraction. 100% of site under bioremediation.	Ongoing process; treated soil remains on site at Mobil terminal. Air extraction system installed in summer 1991 to enhance bioremediation in part of biocell.
II	Nascolite** Millville, NJ CERCLA Fund Lead	Farnaz Saghafi (212)264-4665 Anton Navarajah (609)633-6798 Nicoletta DiForte (212)264-0970	Sediments (sand, silt) / soil (sand, silt) / ground water: methylmethacrylate, lead.	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies were completed 06/92. Started 04/92. Pilot-scale studies are planned.	Ground water: risk-based.	Ex situ treatment, contact stabilization, batch flow. Aerobic conditions, indigenous organisms. Other technologies: filtration, ultraviolet oxidation.	None.
II	Niagara Mohawk Power Corporation* Saratoga Springs, NY CERCLA Enforcement Lead	William R. Jones (315)428-5690 Michael Sherman (315)428-6624	Soil (sand): PAHs.	Laboratory-scale studies were completed 05/92. Started 02/92.	Soil: potential for leaching to ground water.	Ex situ treatment, slurry reactor. Aerobic conditions, indigenous organisms.	Laboratory-scale feasibility study report currently is being prepared. Depending on results, pilot- and full-scale activity may be undertaken. In situ treatment with nutrient addition would be used for soils, and a fluidized bed bioreactor would be used for ground water.
II	Osmose** Buffalo, NY CERCLA State Lead	Jim Harrington (518)485-8792 Jaspal Walia (716)851-7220	Soil (vadose and saturated: silt, clay): wood preserving (benzo(a)pyrene, PAHs), petroleum (fuel oil). Volume: 670 cubic yards.	Full-scale remediation has been under way since 09/90. Total expected cost: $125K.	Soil: wood preserving, 473 mg/kg (risk-based). Soil (vadose and saturated): benzo(a)pyrene, 10 mg/kg; carcinogenic PAHs, 50 mg/kg (risk-based).	Ex situ land treatment. Aerobic conditions, indigenous organisms. 30% of site under bioremediation.	None.
II	Plattsburgh Air Force Base Plattsburgh, NY Federal Facility	Phil Von Bargen (518)565-6672 Jim Lister (518)457-3976	Ground water: petroleum.	Pilot-scale studies are planned. Expected start 03/94.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	This will be a pilot-scale project as part of the Air Force Bioventing Initiative.
II	Syracuse Syracuse, NY UST Lead (State)	Harry Warner (315)426-7519	Soil: petroleum. Volume: 6,000 cubic yards.	Full-scale remediation was completed 10/91. Started 07/90.	Soil: NY Soil Cleanup Levels.	In situ land treatment. Ex situ land treatment.	Late start for first phase; cold weather slowed use of bioremediation. Site was prepared for closure in Fall 1991, but small untreated areas were discovered. This material was separated and moved to an adjacent area for treatment in Spring 1992.

* Indicates a new site.
** Indicates that the site has been updated.

Shading indicates a non-CERCLA site.

FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
III	Allied Chrome Works* Baltimore, MD	Louis DeFilippi (708)391-3251 F. Stephen Lupon (708)391-3224	Sediments / soil / ground water: hexavalent chromium.	Full-scale bioremediation is not planned. Laboratory-scale and pilot-scale studies have been completed.	Soil: hexavalent chromium, 0.05 mg/kg. Ground water: hexavalent chromium, 0.05 ppm. Sediments: hexavalent chromium, 0.05 ppm.	Ex situ treatment, septic tank reactor, continuous flow. Anaerobic conditions, indigenous organisms.	Pilot-scale studies in field indicated that the site geology was too problematical for full-scale investigation and treatment.
III	ARC Gainesville, VA RCRA Lead (Federal)	Robert Stroud (215)597-6688 Patrick Grover (804)225-2863	Soil: solvents (chlorobenzene). Volume: 2,000 cubic yards.	Full-scale remediation was completed 06/91. Started 10/89.	Soil: chlorobenzene, 0.014 mg/kg (technology effectiveness).	In situ treatment, bioventing. Aerobic conditions, exogenous organisms. 5% of site underwent bioremediation.	Facility was required to submit a closure plan to the state of VA; however, this requirement no longer exists.
III	Atlantic Wood Portsmouth, VA CERCLA Enforcement Lead	Vance Evans (215)597-8485 Steve Mihalko (804)255-3263	Sediments / soil: wood preserving (PCP, PAHs), dioxins, furans.	Laboratory-scale studies are being conducted.	Not yet established.	Bioremediation treatment not yet established. Other technologies: in situ soil flushing, soil washing, thermal desorption, incineration.	Feasibility study results currently are being reviewed. Type of treatment won't be determined until review is completed. The presence of dioxins and furans might be a problem.
III	Avtex Fibers Front Royal, VA CERCLA Enforcement Lead	Bonnie Gross (215)597-0491	Ground water: arsenic, zinc, lead, carbon disulfide, cadmium, hydrasulfide.	Laboratory-scale studies are planned. Total expected cost: $9M.	Ground water: arsenic, 0.05 mg/L; zinc, 5 mg/L; lead, 0.05 mg/L; carbon disulfide, 0.7 mg/L; cadmium, 0.01 mg/L.	Ex situ treatment, attached growth reactor. Aerobic conditions. Other technologies: chemical treatment.	Site is undergoing a remedial investigation/feasibility study.
III	Dover Air Force Base Dover, DE Federal Facility Process 1	Milton Beck (302)677-6845 Rob Allen (302)323-4540	Soil (vadose sand) / ground water: petroleum, metals (lead). Volume: 15K cubic yards.	Pilot-scale studies have been under way since 11/92.	Soil (vadose): BTEX, 10 mg/kg; TPH, 1,000 mg/kg; lead, 500 mg/kg (risk-based). Ground water: risk-based.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. Other technologies: vacuum extraction, air sparging.	Problem with free product and ground water contamination.
	Process 2		Soil (sand) / ground water: solvents, iron, manganese. Volume: 50K cubic yards.	Pilot-scale studies have been under way since 01/93.	Not yet established.	In situ treatment, air sparging. Aerobic conditions, indigenous organisms. Other technologies: vacuum extraction.	Site has solvents in ground water, high iron and manganese.
	Process 3		Soil (vadose silt): petroleum, PAHs, TCE.	Pilot-scale studies are planned. Expected start 10/93.	Soil (vadose): BTEX, 10 mg/kg; TPH, 1,000 mg/kg (risk-based).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	None.
	Process 4		Soil (vadose: sand, silt): petroleum. Volume: 300K cubic yards.	Pilot-scale studies are planned. Expected start 09/93. Incurred cost: O&M, $100K. Total expected cost: capital, $1.2M.	Soil (vadose): TPH, 1,000 mg/kg; BTEX, 10 mg/kg (risk-based).	In situ treatment, air sparging, bioventing. Ex situ land treatment. Aerobic conditions, indigenous organisms. Other technologies: vacuum extraction, asphalt binding.	Site has free product soil contamination under aircraft parking apron.
III	Drake Chemical Lock Haven, PA CERCLA Fund Lead	Roy Schrock (215)597-0913	Soil / ground water: pesticides, solvents (DCE), herbicides (fenac).	Full-scale remediation is planned. Currently in predesign.	Not yet established.	Aerobic attached growth.	None.

* Indicates a new site.
** Indicates that the site has been updated.

Shading indicates a non-CERCLA site.

FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
III	L.A. Clarke & Son Fredericksburg, VA CERCLA Enforcement Lead	Gene Wingert (215)597-1727	Sediments / soil: wood preserving. Volume: 119K cubic yards.	Full-scale remediation is planned. Currently in design. Pilot-scale studies have been under way since 07/92. Total expected cost: $23M.	Not yet established.	In situ treatment, creosote recovery. Anaerobic conditions, exogenous organisms. Other technologies: soil flushing. 25% of site will undergo bioremediation.	None.
III	Ordnance Works Disposal Area** Morgantown, WV CERCLA Enforcement Lead	Melissa Whittington (215)597-1286 Janet Wolfe (304)558-2745	Soil: PAHs, arsenic, cadmium, copper, lead. Volume: 42K cubic yards.	Full-scale remediation is planned. Laboratory-scale studies have been under way since 02/93. Expected completion 11/93. Pilot-scale studies are planned. Expected start 11/93. Total expected cost: $8.3M.	Soil: carcinogenic PAHs, 44.7 mg/kg (risk-based).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Other technologies: solidification of inorganics.	Unilateral administrative order issued June 1990. There may be problems at this site associated with: (1) achieving the cleanup levels, (2) extrapolating data from the treatability studies, and (3) determining usable amendments for the treatability studies.
III	Whitmore Labs Myerstown, PA CERCLA Enforcement Lead	Christopher Corbett (215)597-8995 Noreen Chamberlain (717)657-6309	Soil (vadose and saturated): solvents (benzene, trichloroethene, tetrachloroethene, aniline), arsenic. Volume: 4,000 cubic yards.	Full-scale remediation is planned. Currently in predesign.	Soil (vadose): benzene, 0.009 mg/kg; trichloroethene, 0.017 mg/kg; tetrachloroethene, 0.051 mg/kg; aniline, 0.009 mg/kg. Soil (saturated): benzene, 0.002 mg/kg; trichloroethene, 0.004 mg/kg; tetrachloroethene, 0.012 mg/kg; aniline, 0.002 mg/kg.	Ex situ treatment. Other technologies: chemical treatment, fixation, incineration, containment, pump and treat. Less than 10% of site will undergo bioremediation.	None.
IV	Alabama State Docks** Mobile, AL RCRA-Federal for soil; RCRA-State for ground water Process 1 Process 2	Jason Darby (404)347-3433 Clyde Sherer (205)271-7726	Ground water: wood preserving (PCP), arsenic, chromium, benzene, lead. Soil (sand, silt, clay, humus rich matter): wood preserving (PCP).	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies have been completed. Pilot-scale studies are planned. Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies have been completed. Pilot-scale studies are planned.	Ground water: arsenic, 0.05 mg/L; chromium, 0.05 mg/L; benzene, 0.005 mg/L. Not yet established.	Ex situ treatment, fixed bed, continuous flow. Aerobic conditions. Other technologies: granular activated carbon. In situ land treatment. Ex situ treatment, slurry reactor.	Problems with regulatory concerns when managing treated material. RCRA land disposal restrictions (LDRs) may interfere with land treatment of contaminated soils.
IV	American Creosote Works** Jackson, TN CERCLA Fund Lead O.U.#2	Tony DeAngelo (404)347-7791 Ron Sells (901)423-6600 Betty Maness (901)423-6600	Ground water: wood preserving (PCP), chromium (+3), copper, silver.	Full-scale remediation is planned. Laboratory-scale and pilot-scale studies are planned.	Not yet established.	Bioremediation treatment not yet established.	Hydrogeologic investigation under way. Remedial action contingent upon receiving 10% cost share from state. Funds available for treatability studies only.

* Indicates a new site.
** Indicates that the site has been updated.

Shading indicates a non-CERCLA site.

FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
	O.U.#3		Sludge / soil (vadose and saturated: sand, silt): wood preserving (PAHs, phenols), chromium (+3), copper, silver.	Full-scale remediation is planned. Laboratory-scale and pilot-scale studies are planned.	Not yet established.	Ex situ land treatment. Aerobic conditions, indigenous organisms.	State may not have 10% cost share for any remedial action to be undertaken.
IV	American Creosote Works—Pensacola** Pensacola, FL CERCLA Fund Lead	Madolyn Streng (404)347-2643 Doug Fitton (904)488-0190 Beverly Houston (404)347-3866	Soil: wood preserving (PCP, PAHs), dioxin. Volume: 30K cubic yards.	Full-scale bioremediation is not planned. Laboratory-scale studies were completed 11/91. Total expected cost: $5M.	Soil: PCP, 30 mg/kg; PAHs, 50 mg/kg; dioxin (in situ), 2.5 µg/kg; dioxin (ex situ), 1 µg/kg (risk-based).	In situ treatment. Ex situ treatment, sequencing batch reactor, slurry reactor, batch flow. Aerobic conditions. Other technologies: soil washing, incineration possible for dioxin-contaminated soils.	Bioremediation was not effective for remediation of dioxins in soils.
IV	Brown Wood Preserving Live Oak, FL CERCLA Enforcement Lead	Martha Berry (404)347-2643 Charles Logan (904)488-0190	Soil: wood preserving (PCP, PAHs). Volume: 9,000 cubic yards.	Full-scale remediation was completed 12/91. Started 10/88.	Soil: PAHs, 100 mg/kg.	Ex situ land treatment.	None.
IV	Cabot Koppers Gainesville, FL CERCLA Enforcement Lead	Martha Berry (404)347-2643 Kelsey Helton (904)488-0190	Soil: wood preserving (PAHs, phenol, naphthalene, fluorine, PCP, arsenic, chromium). Volume: 6,700 cubic yards.	Full-scale remediation was completed 04/89.	Soil: carcinogenic PAHs, 0.59 mg/kg; phenol, 4.28 mg/kg; naphthalene, 211 mg/kg; fluorine, 323 mg/kg; PCP, 2.92 mg/kg; arsenic, 27 mg/kg; chromium, 92.7 mg/kg.	In situ treatment. Other technologies: soil washing, solidification. 50% of site underwent bioremediation.	None.
IV	Cape Fear Wood Preserving Fayetteville, NC CERCLA Fund Lead	Jon Bornholm (404)347-7791	Sediments / soil / ground water and surface water: wood preserving (arsenic, PAHs, chromium). Volume: 4,000 cubic yards.	Full-scale remediation is planned. Currently in design. Laboratory-scale studies were completed 01/90. Pilot-scale studies are planned. Expected start 07/94.	Soil: PAHs, 1 mg/kg; carcinogenic PAHs, 2.5 mg/kg; arsenic, 94 mg/kg; chromium, 88 mg/kg. Surface water: arsenic, 12 µg/L. Ground water: PAHs, 14 mg/L; carcinogenic PAHs, 10 µg/L. Sediments: arsenic, 94 mg/kg; PAHs, 3 mg/kg.	Ex situ treatment, slurry reactor, batch flow. Other technologies: soil washing, solidification.	Laboratory-scale study was terminated due to time constraints. Biodegradation reduced average total PAH levels and carcinogenic PAH levels from 306 mg/kg and 44 mg/kg, respectively, to 50 mg/L and 14 mg/L in 18 days. Pilot-scale work is needed to confirm effectiveness; overall results suggest longer incubation period could result in further reduction of PAHs to below cleanup goals.
IV	Celanese Fibers Operations Shelby, NC CERCLA Enforcement Lead	Ken Mallary (404)347-7791 Charlotte Jesnick (919)733-2801	Ground water: chromium, solvents (ethylene glycol, acetone, 1,2 DCE), lead.	Full-scale remediation has been under way since 10/88. Expected completion 09/99. Total expected cost: $2M.	Ground water: ethylene glycol, 7 ppm; 1,2 DCE, 0.07 ppm; chromium, 50 ppb (state ARAR).	Ex situ treatment, sequencing batch reactor, aerated tank, batch flow. Aerobic conditions, exogenous organisms. Other technologies: chemical treatment, carbon adsorption, and air stripping used for ground water; rotary kiln incineration, solidification/stabilization to treat sludges and soils. 100% of site under bioremediation.	Biomass upsets decreasing operating efficiency of treatment system. Cause of upsets is unknown to date. COD removal efficiency for seventh operational quarter was 92 percent for wells located close to source. TOC removal efficiency was 87 percent.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
IV	Charleston Air Force Base* Charleston, SC RCRA Lead (Federal)	Sue Davis (803)566-4978 Joe Bowers (803)734-4814 Liz Wilde (404)347-3016	Soil (vadose sand): petroleum (jet fuel), solvents (1,1-dichloroethene, 1,1,1-trichloroethane, trichloroethene, vinyl chloride, trans 1,2-dichloroethene, tetrachloroethene, dichloromethane), lead. Volume: 25 cubic yards.	Pilot-scale studies have been under way since 11/92. Expected completion 12/93.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. Other technologies: pump and treat for ground water plume. Less than 10% of site under bioremediation.	Bioventing will be difficult due to high ground water table and seasonal variation of ground water elevation and direction.
IV	Coleman-Evans** White House, FL CERCLA Fund Lead	Tony Best (404)347-2643 Peter Grasel (904)488-0190	Soil (sand, loam): wood preserving (PCP), arsenic. Volume: 27K cubic yards.	Full-scale remediation is planned. Currently in design. Expected start 06/93. Expected completion 06/94. Laboratory-scale studies have been completed. Total expected cost: $8.6M.	Soil: PCP, 25 mg/kg.	Ex situ treatment, slurry reactor, batch flow. Aerobic conditions, exogenous organisms. Other technologies: soil washing, solidification/stabilization. 100% of site will undergo bioremediation.	Problem with wood chip removal from soils; dioxins have been identified and are being evaluated. Bioremediation will be ineffective for dioxins.
IV	Dubose Oil** Cantonment, FL CERCLA Enforcement Lead	Mark Fite (404)347-2643 George Linder (904)488-0190 Kenneth Stockwell (404)325-0770	Soil (sand, clay): TPNA, PCP, petroleum, solvents (TCE, PCE). Volume: 15K cubic yards.	Full-scale remediation is planned. Currently in design. Laboratory-scale studies have been completed. Pilot-scale studies are planned. Total expected cost: $3M.	Soil: TPNA, 50 mg/kg; PCP, 50 mg/kg; xylene, 65 mg/kg; benzene, 10 mg/kg; TCE, 0.05 mg/kg; PCE, 0.07 mg/kg.	Ex situ treatment, pile. Aerobic conditions, indigenous organisms. Other technologies: carbon adsorption for treatment of wastewater. 90% of site will undergo bioremediation.	Pilot study was delayed due to waiting for results of dioxins test.
IV	Escambia Wood Preserving Site—Brookhaven** Brookhaven, MS CERCLA Fund Lead	De'Lyntoneus Moore (404)347-3931	Soil (loam): wood preserving (PCP). Volume: 200 cubic yards.	Full-scale bioremediation is not planned. Pilot-scale studies were completed 11/92. Started 06/92.	Soil: risk-based.	Ex situ treatment. Aerobic conditions, exogenous and indigenous organisms. 1% of site underwent bioremediation.	There is a lack of information on success of technology at field-scale level; however, results of field treatability study showed reduction in PCP and creosote—up to 86% for PCP, and 96% for 3-ringed PAH creosote compounds.
IV	Koppers/Florence Florence, SC RCRA Lead (Federal)	Mike Arnett (404)347-7603	Soil: wood preserving (PCP, PAHs).	Full-scale remediation is planned. Currently in predesign.	Not yet established.	Ex situ land treatment. Exogenous and indigenous organisms. Other technologies: ground water extraction, pretreatment, and discharge to a POTW. 33% of site will undergo bioremediation.	None.
IV	Langdale Facility Sweetwater, TN RCRA Lead (Federal)	Charles Burroughs (615)741-3424	Sludge / soil: wood preserving.	Full-scale remediation was completed 01/89.	Not supplied.	Ex situ land treatment. Exogenous organisms.	None.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
IV	Orkin Facility* Fort Pierce, FL TSCA Lead (State)	Joe Malinowski (404)888-2895	Soil (sand) / ground water: pesticides (chlordane, heptachlor). Volume: 200 cubic yards.	Full-scale remediation is planned. Currently in design. Expected start 12/93. Expected completion 12/95.	Not yet established.	In situ land treatment, hydrogen peroxide, nutrient addition (soil, water). Aerobic and anaerobic conditions, indigenous organisms.	None.
IV	Shavers Farm Lafayette, GA CERCLA Fund Lead	Chuck Eger (404)347-3931	Soil: pesticides (dicamba), benzoic acid, dichlorosalicyclic acid, benzonitrite.	Pilot-scale studies have been completed.	Soil: dicamba, 25 mg/kg; benzoic acid, 25 mg/kg; dichlorosalicyclic acid, 25 mg/kg; benzonitrite, 25 mg/kg.	Bioremediation treatment not yet established.	Pilot bench-scale treatability studies being reviewed. Still working out logistics.
IV	Silvex Saint Augustine, FL State Lead	William Burns (904)488-0190 George Hevler (904)288-0190	Ground water: solvents (acetone, benzene, chloroform, cresols, ethylbenzene, 2-butanone, methylene chloride, toluene, 1,1,1-trichloroethane, methyl isobutyl ketone, 2,1,1-dimethylphenol), cadmium, chromium, copper, lead, nickel, silver, zinc.	Full-scale remediation is planned. Currently in design. Laboratory-scale studies were completed 08/91. Started 01/91. Pilot-scale studies were completed 10/92. Started 01/92.	Ground water: acetone, 700 µg/L (risk-based); benzene, 1 µg/L (risk-based); chloroform, 0.7 µg/L (risk-based); cresols, 700 µg/L (risk-based); ethylbenzene, 39 µg/L (proposed MCL); 2-butanone, 680 µg/L (risk-based); methylene chloride, 7 µg/L (risk-based); toluene, 2,000 µg/L (risk-based); 1,1,1-trichloroethane, 200 µg/L; methyl isobutyl ketone, 350 µg/L (risk-based); 2,1,1-dimethylphenol, 39 µg/L (risk-based).	Ex situ treatment, fixed film, continuous flow. Aerobic conditions, exogenous organisms. Other technologies: soil solidification. 100% of site will undergo bioremediation.	None.
IV	Southeastern Wood Preserving Canton, MS CERCLA Fund Lead	Don Rigger (404)347-3931	Soil: wood preserving. Volume: 10K cubic yards.	Full-scale remediation has been under way since 04/90. Total expected cost: $1.7M.	Soil: K001 land ban standards.	Ex situ treatment, slurry reactor, batch flow. Aerobic conditions, exogenous and indigenous organisms. Other technologies: soil washing. 100% of site under bioremediation.	Failed to meet current K001 land ban standards for pyrene and phenanthrene. May be forced to seek treatability variance.
IV	Stallworth Timber** Beatrice, AL RCRA Lead (State) and RCRA Lead (Federal)	Jason Darby (404)347-3433 Stan Sullivan (205)271-7730	Soil (sand, silt) / ground water: wood preserving (PCP).	Full-scale remediation is planned. Currently in predesign.	Not yet established.	In situ treatment, nutrient addition (soil: oxygen, potassium nitrate, potassium phosphate, molasses). Ex situ treatment, activated sludge, continuous flow. Aerobic conditions, exogenous and indigenous organisms. Other technologies: chemical treatment, clarification, ultraviolet oxidation. 100% of site will undergo bioremediation.	None.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
IV	White House Waste** White House, FL CERCLA Fund Lead	Tony Best (404)347-2643 Marvin Collins (904)488-0190	Soil (sand, silt) / ground water: petroleum, solvents (benzo(a)pyrene, chlorobenzene, 1,4-dichlorobenzene, di-n-butyl phthalate, methylene chloride, 2-methyl naphthalene, naphthalene, phenol, tetrachloroethene, trichloroethene, acetone, bis(2-ethylhexyl)phthalat, carbon disulfide, ethylbenzene, methyl ethyl ketone, 3,4-methylphenol), PCB 1260, lead, other inorganics. Volume: 40.7K cubic yards.	Full-scale remediation is planned. Currently in predesign. Expected start 06/93. Expected completion 06/94. Total expected costs: capital, $15.5M; O&M, $3.4M.	Soil: benzene, 1.13 µg/kg; benzo(a)pyrene, 0.192 mg/kg; chlorobenzene, 970 mg/kg; 1,4-dichlorobenzene, 0.012 mg/kg; methylene chloride, 29.3 mg/kg; PCB 1260, 0.09 mg/kg; 2-methyl naphthalene, 2.2 mg/kg; naphthalene, 0.261 mg/kg; phenol, 0.549 mg/kg; tetrachloroethene, 4.3 mg/kg; toluene, 14.4K mg/kg; trichloroethene, 0.0447 mg/kg (risk-based). Ground water: acetone, 0.0016 mg/L (risk-based); benzene, 0.005 mg/L (ARAR-based); benzo(a)pyrene, 0.0002 mg/L (ARAR-based); bis(2-ethylhexyl)phthalat, 0.004 mg/L (ARAR-based); carbon disulfide, 1.64 mg/L (risk-based); ethylbenzene, 0.7 mg/L (ARAR-based); methyl ethyl ketone, 8.46 mg/L (risk-based); 3,4-methylphenol, 0.85 mg/L (risk-based); naphthalene, 9,700 mg/L (risk-based); 2-methyl naphthalene, 0.067 mg/L (risk-based); phenol, 10 mg/L (risk-based); toluene, 1 mg/L (ARAR-based); trichloroethene, 0.005 mg/L (ARAR-based); xylene, 10 mg/L (ARAR-based).	Ex situ treatment, slurry reactor, batch flow. Aerobic conditions, exogenous organisms. Other technologies: soil washing, solidification/stabilization. 100% of pit material at site will undergo bioremediation.	Bioremediation is a proposed remedy, presently under public comment. If accepted, an amended ROD will follow in May 1993. Solidification/stabilization will follow bioremediation in the treatment train due to the presence of lead.
V	Allied Chemical** Ironton, OH CERCLA Enforcement Lead	Jim Van der Kloot (312)353-9309 Kay Gossett (614)385-8501	Sediments (coal and coke fines): PAHs, arsenic. Volume: 500K cubic yards.	Full-scale remediation is planned. Currently in design. Laboratory-scale studies were completed 09/92. Pilot-scale studies have been completed. Total expected cost: $26M.	Sediments: carcinogenic PAHs, 100 mg/kg (risk-based).	In situ treatment. Aerobic conditions, indigenous organisms. Other technologies: incineration with onsite reuse of waste heat; pump and treat for ground water. 50% of site will undergo bioremediation.	Concentrations of contaminants are highly variable, making confirmation of cleanup difficult.
V	Aristech Chemical** Haverhill, OH RCRA Lead (Federal)	Matthew Ohl (312)886-4442 Scott Schermerhorn (614)385-8501 Bud Smith (614)533-5412	Soil (clay): cumene, phenol.	Full-scale remediation was completed 04/92. Incurred cost: $180K. Total expected cost: $258K.	Soil: cumene, 4.67 mg/kg; phenol, 4.1 mg/kg (risk-based).	In situ land treatment, nutrient addition (fertilizer, nitrogen, and phosphorous). Aerobic and anaerobic conditions, exogenous and indigenous organisms.	Soil moisture and temperature were the most difficult factors to control.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
V	Autostyle Kentwood, MI State Lead	Bonnie White (616)456-5071	Ground water: solvents (aromatic ketones), alcohol.	Full-scale remediation has been under way since 09/90.	Not yet established.	Ex situ treatment, fixed film. Aerobic conditions. Other technologies: vacuum extraction, soil vapor extraction for product recovery and soil treatment. 100% of site under bioremediation.	None.
V	B&F Trucking Company Rochester, MN UST Lead (State)	Pat Hanson (612)297-8578 Stephen Thompson (612)297-8603	Soil / ground water: petroleum (lube oil). Volume: 700 cubic yards.	Full-scale remediation was completed 12/92. Started 04/91. Incurred cost: $341K.	Soil: BTEX, 50 mg/kg (risk-based). Ground water: 100 x MN Department of Health RALs.	In situ treatment. Ex situ treatment, sequencing batch reactor, continuous flow. Aerobic conditions, indigenous organisms. 75% of site underwent bioremediation.	Increase in iron concentration in ground water caused iron bacteria and resulting "slime" to accumulate on the surface of pipes and other process equipment. Site now has converted to nonbiological process.
V	Bendix Corporation/Allied Automotive Site St. Joseph, MI CERCLA Enforcement Lead	John Kuhns (312)353-6556 Sally Beebe (517)373-4110	Ground water: solvents (TCE, DCE, DCA, vinyl chloride).	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies are being conducted.	Not yet established.	In situ treatment. Aerobic and anaerobic conditions, indigenous organisms.	Recent sampling has identified much higher TCE concentrations than expected. At these concentrations, TCE potentially might be toxic for aerobic organisms. Additional tests are being conducted to examine the feasibility of a two-phase anaerobic/aerobic system.
V	BP Oil Company** Lima, OH RCRA Lead (Federal)	Gary Vonderembse (419)226-2744	Soil: petroleum (benzo(a)pyrene, benzo(a)anthracene, chrysene, 1-methyl chrysene, 1-methyl naphthalene), barium, cadmium, chromium (III), chromium (VI), lead, nickel, zinc.	Full-scale bioremediation is not planned. Laboratory-scale studies were completed 11/88.	Soil: benzo(a)pyrene, 38 µg/kg; benzo(a)anthracene, 38 µg/kg; chrysene, 37 µg/kg; 1-methyl chrysene, 37 µg/kg; 1-methyl naphthalene, 16 µg/kg (residential risk-based scenario).	In situ land treatment, nutrient addition (anhydrous ammonia). Indigenous organisms.	Land treatment permit was denied. Application of oily sludge took place in November 1990. Working to achieve risk levels of 10^{-5} or 10^{-6} before closing, which will determine the land's final use.
V	Burlington Northern** Brainerd, MN CERCLA—State to start; RCRA—Federal since 1986	David Seep (913)661-7015 Frederick Jenness (612)297-8470 Richard Truax (303)493-3700	Soil (vadose sand) / ground water: wood preserving (PCP). Volume: 10K cubic yards.	Full-scale remediation is being conducted.	Ground water: carcinogenic PCP, 28 mg/L; noncarcinogenic PCP, 300 mg/L.	Ex situ land treatment. Aerobic conditions, indigenous organisms. Other technologies: thermal desorption and pump and treat for ground water. 100% of site under bioremediation.	None.
V	Cliff/Dow Disposal Site** Marquette, MI CERCLA Enforcement Lead	Ken Glatz (312)886-1434 Bruce Van Ottern (517)373-8427	Soil (vadose charcoal/sand mix) / ground water: wood preserving (PAHs), arsenic, copper, lead, mercury. Volume: 9,000 cubic yards.	Laboratory-scale studies were completed 01/93. Started 12/92.	Not yet established.	Ex situ treatment, pile. Aerobic conditions, indigenous organisms. 90% of site will undergo bioremediation.	None.
V	Galesburg/Koppers Galesburg, IL CERCLA State Lead	Brad Bradley (312)886-4742 Steve Davis (217)785-3913	Soil: phenols, chlorophenol, PNAs, PCP, PAHs.	Full-scale remediation is planned. Currently in predesign.	Not yet established.	In situ treatment, nutrient addition. 100% of site will undergo bioremediation.	None.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
V	Hentchells Traverse City, MI UST Lead (State)	Ann Emington (616)775-9729	Soil / ground water: petroleum.	Full-scale remediation was completed 03/89. Started 09/85.	Soil: nondetection levels. Ground water: nondetection levels.	In situ treatment, nutrient addition (soil: mono- and di-sodium phosphate, ammonium choride, water: mono- and di-sodium phosphate, ammonium chloride). Aerobic conditions, indigenous organisms. 75% of site underwent bioremediation.	Iron-forming bacteria clogged the carbon system. Pursuing final cleanup of residue at leading edge of plume. Also need soil verification.
V	Joliet Army Ammunitions Plant Elwood, IL Federal Facility	Dion Novak (312)886-4737 Steve Miller (217)782-1803	Soil: TNT, DNT, RDX.	Full-scale remediation is planned. Currently in design. Laboratory-scale studies have been completed. Pilot-scale studies are being conducted.	Not yet established.	Ex situ treatment, sequencing batch reactor, batch flow. Aerobic conditions, indigenous organisms.	None.
V	Joslyn MFG Brooklyn Center, MN CERCLA State Lead	Ann Bidwell (612)296-7827 Kevin Turner (312)886-4444	Soil (vadose): wood preserving (PCP, PAHs). Volume: 67K cubic yards.	Full-scale remediation has been under way since 08/89. Expected completion 09/94.	Soil (vadose): PCP, 150 mg/kg; PAHs, 100 mg/kg (dermal contact).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Other technologies: ground water pump out system with nonbiological treatment. 35% of site under bioremediation.	Due to extreme rainfall in May 1992, part of Land Treatment Unit was under water. Flooding has delayed treatment of lift 2 soil.
V	K.I. Sawyer AFB Marquette, MI Federal Facility	Maeve Morgan (906)346-2342 Mark Petrie (906)228-6561	Soil (vadose sand): petroleum.	Pilot-scale studies have been under way since 10/92. Expected completion 10/93.	Soil (vadose): benzene, 20 µg/kg; toluene, 16K µg/kg; xylene, 6,000 µg/kg (MDNR Act 307 Type B Criteria).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. Other technologies: a twelve-week study was conducted from November 1990 to February 1991 to evaluate the effectiveness of dual pump versus single pump hydrocarbon recovery for free product on the water table.	Site is located in northern U.S., near Lake Superior. Accumulation of snow and freezing temperatures for more than 6 months of the year make field work and system operation difficult.
V	MacGillis and Gibbs Company Site New Brighton, MN CERCLA Fund Lead	Daryl Owens (312)886-7089 Douglas Robohm (612)296-7717	Ground water: wood preserving (PCP), arsenic, chromium.	Full-scale remediation is planned. Currently in design. Expected start 09/93. Expected completion 04/95. Pilot-scale studies were completed 09/89. Started 07/89. Total expected cost: capital, $260K. Cost per year: O&M, $600K.	Ground water: POTW pretreatment standards.	Ex situ treatment, fixed film, plug flow. Aerobic conditions, indigenous organisms. Other technologies: soil washing and soil incineration are under consideration. 10% of site will undergo bioremediation.	A pilot-scale bioremediation system was tested on site under the SITE program. The results are in a report dated September 1991 (EPA/540/A5-91/001).

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
V	Marathon Station-Ervines Kentwood, MI State Lead	Bonnie White (616)456-5071	Ground water: petroleum (gasoline).	Full-scale remediation has been under way since 01/88.	Ground water: background, nondetection, or risk-based.	Ex situ treatment, fixed film. Aerobic conditions. Other technologies: carbon polish unit to ensure compliance with NPDES permit. Company has been considering soil vapor extraction to enhance process but has not taken steps to implement. Originally also had some product separation (gravity). 95% of site under bioremediation.	System was designed as a decay phase reactor, so periodically has to shut down to allow regrowth of cultures. (This has occurred only once.)
V	Mayville Fire Department Mayville, MI UST Lead (State)	Jon Mayes (517)684-9141	Ground water: petroleum.	Full-scale remediation has been under way since 05/90. Expected completion 01/94.	Ground water: benzene, 1 ppb (risk-based); toluene, 800 ppb (aesthetic DWV); ethylbenzene, 70 ppb (aesthetic DWV); xylenes, 300 ppb (aesthetic DWV).	In situ treatment, air sparging. Aerobic conditions, indigenous organisms. 100% of site under bioremediation.	None.
V	Michigan Air National Guard* Battle Creek, MI Federal Facility	Fred Vollmerhausen (616)969-3233	Soil (vadose: sand, silt): petroleum, heavy metals.	Full-scale remediation is planned. Currently in design. Expected start 09/93. Expected completion 09/94. Pilot-scale studies have been under way since 09/92. Expected completion 09/93. Incurred costs: capital, $3,000; O&M, $48. Total expected costs: capital, $3,000; O&M, $1,268. Costs per year: O&M, $436; total, $436.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. 100% of site will undergo bioremediation.	None.
V	Moss-American** Milwaukee, WI CERCLA Enforcement Lead	Bonnie Eleder (312)886-4885	Sediments / soil (sand, silt, loam): wood preserving. Volume: 86.5K cubic yards.	Full-scale remediation is planned. Currently in predesign. Laboratory-scale and pilot-scale studies are planned.	Soil: wood preserving, 6.1 mg/kg (risk-based). Sediments: wood preserving, 6.1 mg/kg (risk-based).	Ex situ treatment, slurry reactor, batch flow. Aerobic conditions, indigenous organisms. Other technologies: soil washing. 2% of site will undergo bioremediation.	Percent of clay in soil/sediment may reduce efficiency of system. May be difficult to achieve cleanup standard due to high molecular weight PAHs. Surfactants used in working process may interfere with bioslurry system.
V	New Lyme Landfill** New Lyme, OH CERCLA Fund Lead	Ted Smith (312)353-6571	Ground water: solvents (ethylbenzene, methylene chloride, methyl phthalate).	Full-scale remediation is being conducted. Incurred cost: capital, $18.1M. Total expected costs: capital, $20M; O&M, $750K.	Ground water: ethylbenzene, 68 µg/L; methylene chloride, 473 µg/L; methyl phthalate, 9.2 µg/L.	Ex situ treatment, fixed film, rotating biological, continuous flow. Aerobic conditions, exogenous organisms. 100% of site under bioremediation.	There have been some problems with plugging caused by calcium carbonate precipitation and fungi entering with effluent. There also have been algal bloom problems.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
V	Newark Air Force Base* Newark, OH UST Lead (State)	Robert Colson (614)522-7077	Soil (vadose; silt, clay); petroleum (gasoline). Volume: 60 cubic yards.	Full-scale bioremediation is not planned. Pilot-scale studies have been under way since 08/92. Expected completion 08/94. Incurred costs: capital, $35K; O&M, $1,000. Total expected costs: capital, $35K; O&M, $2,000.	Soil (vadose): TPH, 642 mg/kg; gasoline, 360 mg/kg (risk-based).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. 40% of site under bioremediation.	The remediation involves small, localized areas of petroleum product contamination; therefore, the treatability study may accomplish complete remediation of the site.
V	Onalaska Municipal Landfill Lacrosse County, WI CERCLA Fund Lead	Kevin Adler (312)886-7078 Paul Kozol (608)264-6013 Robin Schmidt (608)267-7569	Soil (vadose and saturated sand): solvents (TCE), petroleum (total hydrocarbons), wood preserving (naphthalene). Volume: 5,000 cubic yards.	Full-scale remediation is planned. Currently in design. Remediation expected to complete 09/96. Laboratory-scale studies were completed 03/92. Total expected costs: capital, $400K; O&M, $20K.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. 20% of site will undergo bioremediation.	In final design stage. Construction expected May 1993. Soils outside of landfill to be addressed—methane in landfill.
V	Organic Chemical** Grandville, MI CERCLA Fund Lead	Tom Williams (312)886-6157	Ground water: TCE, toluene, petroleum (lube oil).	Laboratory-scale studies are planned.	Not yet established.	Bioremediation treatment not yet established. Other technologies: levels of organics are so high at the site that bioremediation is not practical until the levels are lowered. Ground water pump and treat with an air stripper and GAC is being used as an interim measure.	Review of dioxin data has revealed that soil will be handled by EPA in Cincinnati. Waiting for feasibility study to do remediation on TCE and toluene. Working on additional plan for oil. Ground water pump and treat began in December 1993.
V	Parke-Davis Holland, MI RCRA Lead (Federal)	Shari Kolak (312)886-6151 Dave Slayton (517)373-8012	Soil / ground water: petroleum, solvents, arsenic, chloride, zinc.	Laboratory-scale and pilot-scale studies are planned.	Not yet established.	In situ treatment. Ex situ treatment, fixed film. Aerobic conditions. Other technologies: air stripping and steam stripping.	None.
V	Reilly Tar Indianapolis, IN CERCLA Enforcement Lead	Dion Novak (312)886-4737 Krista Eskilson (317)243-5088	Ground water: benzene, pyridine, ammonia. Volume: 7M gallons per day.	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies have been under way since 12/91. Total expected cost: $15M.	Not yet established.	Ex situ treatment, sequencing batch reactor, continuous flow. Other technologies: chemical extraction. 100% of site will undergo bioremediation.	60 to 80 feet of aquifier with conductivities of 0.01 to 0.001 with interfingering until units are not continuous (clay); 7,000,000 gallons per day are being pumped from lower zone aquifier.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
V	Reilly Tar & Chemical Company** St. Louis Park, MN CERCLA Enforcement Lead	Daryl Owens (312)886-7089 Douglas Beckwith (612)296-7715 Mike Scott (612)296-7297	Soil (vadose loam): wood preserving (2-fluorobiphenyl, naphthalene, acenapthylene, fluorene, acenapthene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene).	Full-scale remediation is planned. Pilot-scale studies have been under way since 11/92. Expected completion 11/95. Incurred cost: $25K. Total expected cost: $70K.	Not yet established.	In situ treatment, bioventing, nutrient addition. Aerobic conditions, indigenous organisms. Other technologies: carbon adsorption.	Site initiated a 3-year field evaluation of bioventing in November 1992.
V	Seymour Recycling Seymour, IN CERCLA Enforcement Lead Process 1 Process 2	Jeff Gore (312)886-6552 Prabhakar Kasarabada (317)243-5130	Ground water: solvents (vinyl chloride, TCE, DCE, benzene, chloroethane). Volume: 500K gallons. Soil: solvents (vinyl chloride, TCE, DCE). Volume: 111K cubic yards.	Full-scale remediation was completed 09/90. Incurred cost: $1M. Full-scale remediation was completed 09/90. Incurred cost: $750K.	Ground water: drinking water standards. Not supplied.	In situ treatment, nutrient addition. Aerobic conditions, indigenous organisms. Other technologies: vacuum extraction, multi-layer cap. In situ treatment, nutrient addition. Aerobic conditions, indigenous organisms. Other technologies: vacuum extraction, multi-layer cap.	None. Since a multi-layer cap was applied over the bio-applied soil, there is no way to sample the contaminated soil. The RI in 1984 found more than 54 organic chemicals.
V	Sheboygan River and Harbor** Sheboygan, WI CERCLA Enforcement Lead	Bonnie Eleder (312)886-4885 Tom Eggert (608)264-6012 Rick Fox (312)886-7979	Sediments (sand, silt, clay): PCBs. Volume: 2,500 cubic yards.	Full-scale bioremediation is not planned. Laboratory-scale and pilot-scale studies are being conducted.	Not yet established.	In situ treatment, capping of sediments. Ex situ treatment, confined treatment facility (tank). Aerobic and anaerobic conditions, indigenous organisms. Other technologies: armoring (capping)—pilot-scale study, armoring—effects on biodegradation, solidification/stabilization, thermal extraction, chemical dechlorination, solvent extraction.	Delays in pilot-study due to additional lab-scale tests and coordination with ARCS Program as Pilot Demonstration Project for Sheboygan AOC. Project is ongoing.
V	St. Louis River Interlake/Duluth Tar Site Duluth, MN CERCLA State Lead	Ann Bidwell (612)296-7827	Sediments / soil: VOCs, PAHs.	Full-scale remediation is planned. Currently in predesign.	Not yet established.	Bioremediation treatment not yet established. Other technologies: "pure tar" found in isolated "tar seeps" at the site will be thermally destroyed as fuel.	Remedy for PAH-contaminated soils and sediments has not been selected. The supplemental RI report for the soils operable unit currently is being completed.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
V	Union Carbide—Marietta Facility** Marietta, OH CERCLA Enforcement Lead	Kathleen Warren (312)353-6756 Scott Bergreen (614)385-8501 Terry Roundtree (312)353-3236	Soil / ground water: VOCs, dioxin, monochlorinated biphenyls, dichlorinated biphenyls, PCBs, aluminum, manganese.	Laboratory-scale studies have been completed.	Not yet established.	In situ land treatment (soil). Ex situ treatment, activated sludge (ground water). Aerobic and anaerobic conditions, exogenous and indigenous organisms. Other technologies: GAC.	Site still is in FS stage. A treatability study has been completed. The ROD should be completed by September 1993.
V	Upjohn Company Portage Facility Kalamazoo, MI RCRA Lead (Federal)	Lorna Jereza (312)353-5110 Greg Rudloff (312)335-3478	Soil / ground water: solvents.	Full-scale remediation is planned. Currently in predesign. Pilot-scale studies have been under way since 01/87.	Not yet established.	Ex situ treatment, fixed film biomass with continuous flow (ground water). Aerobic conditions, indigenous organisms. Other technologies: in situ soil flushing, vacuum extraction.	Possible problems with low winter temperatures.
V	West K&L Avenue Landfill Kalamazoo, MI CERCLA Enforcement Lead	Dan Cozza (312)886-7252	Ground water: solvents (acetone, benzene, TCE, vinyl chloride, 1,2-dichloroethane, xylene, toluene, trans-1,2-DCE, ethylbenzene, 1,1-dichloroethane).	Laboratory-scale and pilot-scale studies are being conducted. Total expected cost: $2.2M.	Ground water: acetone, 700 ppb; benzene, 1 ppb; vinyl chloride, 0.02 ppb; 1,2-dichloroethane, 0.4 ppb; xylene, 20 ppb; toluene, 40 ppb; trans-1,2-DCE, 100 ppb; ethylbenzene, 30 ppb; 1,1-dichloroethane, 700 ppb.	Aerobic conditions. Other technologies: depending on results of ground water samples during pump test: precipitation of metals and a carbon filter for the vinyl chloride may need to be added.	Laboratory-scale microcosms and pilot-scale lysimeter systems are being used to assess the biodegradative capacity of the aquifer and landfill material. Results are scheduled to be reported in November 1993. Potential problems include treatment of vinyl chloride and handling of water after treatment. Discharge to POTW would be possible only with the installation of 3 miles of sewer line, and no surface water discharge is possible, so treated ground water must be reinjected.
V	Wright-Patterson Air Force Base* Dayton, OH Federal Facility	John Wolfe (513)257-0178	Soil (vadose: sand, silt, clay): petroleum (jet fuel). Volume: 7,500 cubic yards.	Pilot-scale studies are planned. Expected completion 03/94.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. 100% of site will undergo bioremediation.	None.
VI	Atchinson Santa Fe, NM CERCLA Enforcement Lead	Ky Nichols (214)655-6730 Susan Morris (505)827-2890	Sediments (silt) / soil (sand, silt): petroleum (diesel), chlorides. Volume: 28K cubic yards.	Full-scale remediation has been under way since 07/92. Total expected cost: $3M.	Not yet established.	In situ land treatment, nutrient addition (soil: phosphate and nitrogen; sediments: phosphate and nitrogen). Ex situ land treatment. Aerobic conditions, indigenous organisms. 100% of site under bioremediation.	Possible problem with high chloride content in soil and sludges.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
VI	Dow Chemical Company—Louisiana Division Plaquemine, LA RCRA Lead (Federal)	Madeline Murphy (504)765-0585 Jill McCullough (504)389-8493	Ground water: solvents (1,2-dichloroethane, 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethylene, chloroethane). Volume: 90K cubic yards.	Laboratory-scale studies were completed 12/90. Pilot-scale studies have been under way since 03/93. Incurred costs: capital, $250K; O&M, $10K. Total expected cost: capital, $1M. Cost per year: O&M, $50K.	Not yet established.	In situ treatment, nutrient addition. Anaerobic conditions, indigenous organisms. Other technologies: pump and treat. Less than 1% of site under bioremediation.	Permeability of contaminated zones is low; supply (injection) of nutrients is difficult. All bioactivity may occur at the well screen, thereby plugging the screen.
VI	French Limited** Crosby, TX CERCLA Enforcement Lead	Judith Black (214)655-6735 Louis Rogers (512)463-8188	Sediments (sand, silt) / sludge / soil (sand, silt, clay) / ground water: PCBs, arsenic, hazardous contaminants, petroleum (BAP, VOCs), arsenic.	Full-scale remediation has been under way since 01/92. Total expected cost: $90M.	Ground water: MCLs (risk-based). Sludge: BAP, 9 ppm; PCBs, 23 ppm; VOCs, 43 ppm; arsenic, 7 ppm; benzene, 14 ppm.	In situ treatment, air sparging, oxygen source, nutrient addition (soil, water, sediments). Aerobic conditions, indigenous organisms. Other technologies: stabilization of residue, if necessary. 100% of site under bioremediation.	None.
VI	Hudson Refining Company** Cushing, OK RCRA Lead (Federal)	Bryon Heineman (214)655-8318	Soil (vadose: sand, silt, loam): petroleum (lube oil), wood preserving (PAHs), Volume: 145K cubic yards.	Full-scale remediation has been under way since 01/86.	Soil (vadose): 30% to 50% reduction of contaminants.	In situ land treatment, nutrient addition. Aerobic conditions, indigenous organisms. Other technologies: excavation of soils exhibiting oil and grease concentrations greater than 20,000 ppm. 40% of site under bioremediation.	Lack of microorganisms; state order failed to specify cleanup levels; recontamination at nearby refinery.
VI	Kelly Air Force Base* San Antonio, TX Federal Facility	Dennis Guadarrama (512)925-3100 Mark Weeger (512)908-2361	Soil (vadose clay): petroleum (jet fuel), solvents (PCE, TCE, vinyl chloride, DCE).	Full-scale remediation has been under way since 02/93. Expected completion 09/94.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. Other technologies: pump and treat for ground water.	Bioventing to be used only within S-4 area of Kelly AFB on soils with fuel related contamination.
VI	North Cavalcade Street** Houston, TX CERCLA State Lead	Deborah Griswold (214)655-6715 Louis Rogers (512)463-8188 Larry Wright (214)655-6715	Soil (sand, silt, clay) / ground water: wood preserving (benzene, PAHs). Volume: 5,500 cubic yards.	Full-scale remediation is planned. Laboratory-scale studies have been completed. Pilot-scale studies have been under way since 01/92. Total expected cost: $4M.	Soil: benzene, 0.04 mg/kg; carcinogenic PAHs, 1 mg/kg (risk-based).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Other technologies: soil washing, ground water pump and treat via separation and carbon adsorption. 100% of site will undergo bioremediation.	Winter rain has significantly slowed the pilot study.
VI	Old Inger Darrow, LA CERCLA State Lead	Paul Sieminski (214)655-6710 Sandra Greenwich (504)765-0487	Sludge / soil: petroleum. Volume: 200K cubic yards.	Full-scale remediation has been under way since 04/92. Expected completion 04/99. Incurred cost: $5.4M.	Soil: contaminant reduction from 76% to 4%. Sludge: contaminant reduction from 76% to 4%.	Ex situ land treatment, continuous flow. Aerobic conditions, indigenous organisms. Other technologies: granular activated carbon. 70% of site under bioremediation.	None.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
VI	Sheridan Disposal Services Hempstead, TX CERCLA Enforcement Lead	Gary Bombgarten (214)655-6749	Sludge / soil (sand, silt, clay) / surface water: solvents (benzene, toluene, ethylbenzene, phenol), PCBs. Volume: 40K cubic yards.	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies have been completed. Pilot-scale studies were completed 12/91. Started 04/91. Total expected cost: $28M.	Soil/sludge/surface water: PCBs, 25 mg/kg (PCBs as indicators of other organics).	Ex situ treatment, slurry reactor. Aerobic conditions. Other technologies: stabilization of residues. 100% of site will undergo bioremediation.	Pilot study completed; report finalized August 1993.
VI	Texas Eastern Gas Pipeline** Saint Francisville, LA TSCA Lead (Federal)	Joan Blake (202)260-6236	Soil: PCBs.	Laboratory-scale and pilot-scale studies are being conducted.	Not yet established.	Ex situ treatment. Aerobic conditions, exogenous and indigenous organisms.	Treatability study being carried out by a contractor hired by Texas Eastern.
VII	Amoco Refinery** Sugar Creek, MO RCRA Lead (state)	Tom Ratermann (314)751-3176 Alan Hancock (913)551-7647	Soil (silt, clay): petroleum (phenanthrene, pyrene, naphthalene), lead. Volume: 137K cubic yards.	Full-scale remediation has been under way since 01/90. Total expected costs: capital, $10M; O&M, $13M.	Not yet established.	Ex situ treatment, aerated lagoon, land treatment, batch flow. Aerobic conditions, indigenous organisms. Other technologies: a decoiling step may be used if EPA allows resource recovery of oil without invoking Land Disposal Restrictions. 5% of site under bioremediation.	There have been material handling problems such as mixing sludge for uniformity and providing enough oxygen without cooling the pond below an effective temperature.
VII	Conservation Chemical** Kansas City, MO CERCLA Enforcement Lead	Steve Auchterlonie (913)551-7778	Ground water: phenols, solvents (semivolatiles, VOCs), cyanide complexes, nickel, zinc. Volume: 200 gallons per minute.	Full-scale remediation has been under way since 01/90. Incurred cost: capital, $110K. Cost per year: O&M, $25K.	Ground water: VOCs, 10 ppb; phenols, 1 ppb (Missouri drinking water standards).	Ex situ treatment, fixed film, continuous flow. Aerobic conditions, exogenous organisms. Other technologies: carbon adsorption, lime precipitation, and sulfide precipitation in series. 100% of site under bioremediation.	None.
VII	Fairfield Coal & Gas** Fairfield, IA CERCLA Enforcement Lead	Steve Jones (913)551-7755 Johanshir Golchin (515)281-8925	Soil (saturated: sand, silt, clay) / ground water: coal tar (benzene, ethyl benzene, toluene, xylene, PAHs).	Pilot-scale studies have been under way since 12/91. Expected completion 12/93. Total expected cost: $1.6M.	Soil (saturated): benzene, 241 mg/kg (risk-based); PAHs, 500 mg/kg (5 x risk-based); carcinogenic PAHs, 100 mg/kg (risk-based). Ground water: benzene, 1 ppb (risk-based); carcinogenic PAHs, 200 ppt (best detection level).	In situ treatment, injection and extraction wells, hydrogen peroxide, nutrient addition (water: nitrate). Aerobic conditions, indigenous organisms. Other technologies: thermal treatment of contaminant source areas and pump and treatment of ground water by carbon adsorption with polymer injection and settling.	Possible future problems due to poor transmissivity of the aquifer.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
VII	International Paper Joplin, MO RCRA Lead (state)	Rob Morrison (314)751-3176	Soil (silt, loam): wood preserving (PCP, PAHs). Volume: 70K cubic yards.	Full-scale remediation is planned. Currently being installed. Total expected cost: $9M.	Soil: Sum of the concentrations of 24 aromatic compounds is less than 600 mg/kg (risk-based and state-required).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Other technologies: chemical treatment, soil washing proposed but restricted by Land Disposal Restrictions. 100% of site will undergo bioremediation.	Bioremediation failed at site due to lack of temperature and moisture control; the units were flooded, blocking oxygen transfer. Steps are being taken to control moisture and temperature by covering basins (10+ acres under roof). Land disposal restrictions limit cleanup options.
VII	Offutt Air Force Base* LaPlatte, NE Federal Facility	Philip Cork (402)294-4087 Ed Louis (402)471-4230 Frank Werner (402)294-4087	Soil (vadose: sand, silt): petroleum (TRPH), arsenic, barium, lead, zinc. Volume: 700 cubic yards.	Pilot-scale studies have been under way since 08/92.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. 10% of site under bioremediation.	Pilot-scale system has been in operation since August 1992. No significant information to report yet.
VII	Park City** Park City, KS CERCLA State Lead	John Wilson (405)332-8800	Ground water: petroleum (lube oil), benzene. Volume: 700K cubic feet.	Full-scale remediation has been under way since 12/92. Incurred cost: $275K. Total expected cost: $650K.	Ground water: benzene, 5 µg/L (drinking water standards).	In situ treatment (ground water), possible bioventing for soils, nutrient addition (ammonium chloride and nitrate). Aerobic and anaerobic conditions. Other technologies: in situ soil flushing, soil washing, denitrification of BTEX.	Site is serving as a test case for new Kansas environmental regulations.
VII	Scott Lumber Alton, MO CERCLA Fund Lead	Bruce Morrison (913)236-3881	Soil (vadose silty clay): wood preserving (naphthalene, acenaphthalene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(b)fluoranthene, benzo(a)anthracene, chrysene, benzo(k)fluoranthene, benzo(a)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene, indeno(1,2,3-cd)pyrene, PAHs). Volume: 15.9K tons.	Full-scale remediation was completed 11/91. Started 06/90. Incurred costs: capital, $700K; O&M, $500K.	Soil (vadose): benzo(a)pyrene, 14 mg/kg; PAHs, 500 mg/kg.	Ex situ land treatment, 7 acres closed system water recirculation with 2-ft thick clay liner. Aerobic conditions, indigenous organisms. 90% of site underwent bioremediation.	Health-based risk levels for PAHs were changing and inconsistent.
VII	Sioux City Pilot Study Sioux City, IA CERCLA State Lead	Johanshir Golchin (515)281-8925	Soil (silty clay loam): PAHs, petroleum (lube oil), cyanide. Volume: 100K cubic yards.	Pilot-scale studies were completed 10/91. Started 08/91. Incurred cost: capital, $250K. Total expected cost: capital, $50-100 per cubic yard.	Soil: PAHs, 500 mg/kg; carcinogenic PAHs, 250 mg/kg.	Ex situ land treatment. Aerobic and anaerobic conditions, exogenous and indigenous organisms. Other technologies: chemical treatment. 90% of site underwent bioremediation.	High soil moisture, large area of operation, low temperatures, and other climatic obstacles.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
VII	Vogel Paint & Wax** Maurice, IA CERCLA State Lead	Steven Jones (913)551-7755 Bob Drustrup (515)281-8900	Soil (silt, clay): petroleum (lube oil), solvents (MEK), lead, mercury. Volume: 10K cubic yards.	Full-scale remediation has been under way since 10/91. Total expected cost: $2M.	Not yet established.	Ex situ land treatment, batch flow. Aerobic conditions, indigenous organisms. Other technologies: air stripping of ground water, product recovery.	Volatilization control/air monitoring being evaluated.
VIII	Burlington Northern Glendive, MT Water Quality Bureau Lead	Terry Webster (406)444-2406	Soil: petroleum (diesel).	Full-scale remediation has been under way since 01/91.	Soil: diesel, 100 mg/kg (EPA Recommended Standard).	Ex situ land treatment; active tillage, moisture and nutrient control; seasonal monitoring of contaminants. Monitoring below treatment zone once a year for leaching. Aerobic conditions, indigenous organisms. 30% of site under bioremediation.	None.
VIII	Burlington Northern Tie Plant Somers, MT CERCLA Enforcement Lead	Jim Harris (406)449-5414 Ben Quinones (406)449-4067	Soil / ground water: wood preserving (PAHs). Volume: 82K cubic yards.	Full-scale remediation is planned. Currently in design. Pilot-scale studies are being conducted. Total expected cost: $11M.	Soil: carcinogenic PAHs, 36 mg/kg (risk-based). Ground water: carcinogenic PAHs, 0.03 µg/L (water quality criteria).	In situ treatment. Ex situ land treatment. Aerobic conditions, indigenous organisms. Other technologies: in situ soil flushing, surface treatment of extracted ground water by either UV or carbon adsorption is proposed. 80% of site will undergo bioremediation.	Pilot-scale field activities have been initiated because of low soil transmissivities. Onsite pumping tests were completed in the third quarter of FY1991. A portion of site is adjacent to large lake.
VIII	Conoco Landfarm Billings, MT RCRA Lead (state)	Mark Hall (406)444-4096	Sludge / soil: K048 organics, K051 organics, K048 metals, K051 metals, petroleum. Volume: 77.8K tons.	Full-scale remediation has been under way since 01/73.	Sludge: K048 metals, 1,000 ppm; K051 metals, 1,000 ppm (closure performance standards).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Other technologies: chemical adsorption, ion exchange, precipitation. 65% of site under bioremediation.	Conoco Billings Landfarm is seeking a No Migration Variance. The facility maintains a Montana Hazardous Waste Permit (MTHWP-88-02).
VIII	Exxon Landfarm Billings, MT RCRA Lead (state)	Mark Hall (406)444-4096	Sludge: K049 organics, K050 organics, K051 organics, K049 metals, K050 metals, K051 metals. Volume: 45K tons.	Full-scale remediation has been under way since 01/80.	Sludge: K049 metals, 1,000 ppm; K050 metals, 1,000 ppm; K051 metals, 1,000 ppm (closure performance standard).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Other technologies: chemical adsorption, ion exchange, precipitation.	Exxon Landfarm (Billings) is seeking a No Migration Variance. The facility maintains a Montana Hazardous Waste Permit (MTHWP-88-01).
VIII	Geraldine Airport Geraldine, MT CERCLA State Lead	Carol Fox (406)449-4067	Soil (vadose: sand, silt, loam, clay): pesticides (aldrin, dieldrin, endrin, chlordane, toxaphene, β-BHC, 4,4'-DDE, 4,4'-DDT, 4,4'-DDD), herbicides (2,4-D).	Full-scale remediation is planned. Currently in predesign.	Not yet established.	In situ treatment. Ex situ treatment. Aerobic and anaerobic conditions, indigenous organisms.	None.
VIII	Hill Air Force Base Salt Lake City, UT Federal Facility	Robert Stites (303)294-1974	Soil: petroleum (JP-4 jet fuel).	Full-scale remediation has been under way since 09/91. Expected completion 09/93.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. Other technologies: vapor venting. 100% of site under bioremediation.	If Hill AFB can get funding, bioventing could be conducted on soils with different contaminant mixtures: (1) gasoline and chlorinated solvents, and (2) petroleum hydrocarbons, JP-4 jet fuel, dioxins/furans, and solvents.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
VIII	Idaho Pole Company Bozeman, MT CERCLA State Lead	Jim Harris (406)449-5414 Kevin Kirley (406)449-4067 Janie Stiles (406)449-4067	Sediments / soil / ground water: pentachlorophenol, PAHs, dioxins/furans.	Full-scale remediation is planned. Currently in predesign.	Not yet established.	In situ treatment, oxygen enhancement, nutrient addition (soil, water, sediments). Ex situ treatment, fixed film, slurry reactor. Aerobic conditions, indigenous organisms. Other technologies: in situ soil flushing.	Dioxins and furans inhibit bioremediation of other contaminants.
VIII	Joliet Weed Control District Joliet, MT CERCLA State Lead	Carol Fox (406)449-4067	Soil (vadose: sand, silt, loam, clay): herbicides (2,4-D, dicamba, MCPA).	Full-scale remediation is planned. Currently in design. Pilot-scale studies were completed 09/91.	Not yet established.	In situ treatment. Ex situ treatment. Aerobic and anaerobic conditions, indigenous organisms.	Pilot-scale study did not have adequate controls.
VIII	Lake County Weed Control Ronan, MT CERCLA State Lead	Carol Fox (406)449-4067	Soil (vadose: sand, silt, loam, clay): pesticides (aldrin, dieldrin, endrin, methoxychlordane, chlordane, γ-BHC, β-BHC, 4,4'-DDE, 4,4'-DDT, 4,4'-DDD), herbicides (2,4-D, dicamba, picloram (tordon), atrazine), triallates (far-go).	Full-scale remediation is planned. Currently in design. Pilot-scale studies were completed 06/92.	Not yet established.	In situ treatment. Ex situ treatment. Aerobic and anaerobic conditions, indigenous organisms.	None.
VIII	Libby Ground Water Site Libby, MT CERCLA Enforcement Lead	Jim Harris (406)449-5415	Soil / ground water: wood preserving (PAHs, pyrene, PCP, dioxin, naphthalene, phenanthrene, benzene, arsenic). Volume: 45K cubic yards.	Full-scale remediation has been under way since 05/91. Incurred cost: $4M.	Soil: carcinogenic PAHs, 88 mg/kg; pyrene, 7.3 mg/kg; PCP, 37 mg/kg; dioxin, 1 µg/kg; naphthalene, 8 mg/kg; phenanthrene, 8 mg/kg. Ground water: carcinogenic PAHs, 40 µg/L; noncarcinogenic PAHs, 400 µg/L; PCP, 1.05 mg/L; benzene, 5 mg/L; arsenic, 50 mg/L.	In situ treatment (ground water), ex situ land treatment (soil), hydrogen peroxide (water), nutrient addition (soil, water). Ex situ treatment, bioreactor for ground water. Aerobic conditions, indigenous organisms. 75% of site under bioremediation.	Oil-water separation in bioreactor has been a problem because free product has about the same specific gravity as water. Pyrene degradation rates in land treatment units for soils have been low.
VIII	Miles City Airport Miles City, MT CERCLA State Lead	Carol Fox (406)449-4067	Soil (vadose and saturated): pesticides (aldrin, dieldrin, methyloxychlordane, chlordane, α-BHC, γ-BHC, β-BHC, 4,4'-DDE, 4,4'-DDT, 4,4'-DDD, ethyl parathion, endrin), herbicides (2,4-D, picloram (tordon), atrazine), triallates (far-go).	Full-scale remediation is planned. Currently in predesign.	Not yet established.	In situ treatment. Ex situ treatment. Aerobic and anaerobic conditions, indigenous organisms.	None.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
VIII	Montana Pole Butte, MT CERCLA State Lead	Brian Antonioli (406)449-4067 Sara Weinstock (406)449-5414	Sediments (silt) / soil (silt) / ground water: PCP. Volume: 250K cubic yards.	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies are being conducted. Total expected costs: capital, $10K; O&M, $300K.	Not yet established.	Bioremediation treatment not yet established. Other technologies: in situ soil flushing, soil washing.	The Montana Pole Site is in the RI/FS stage and no remediation currently is taking place. However, treatability studies have recently been conducted and reports are being revised at this time.
VIII	Montana Rail Link—East Helena East Helena, MT Water Quality Bureau	Terry Webster (406)444-2406	Soil: petroleum (diesel).	Full-scale remediation has been under way since 05/92.	Soil: diesel, 100 mg/kg (EPA Recommended).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Active land tillage, moisture and nutrient control, seasonal monitoring for leachate below treatment zone.	None.
VIII	Montana Rail Link—Missoula Missoula, MT Water Quality Bureau	Terry Webster (406)499-2406	Soil: petroleum.	Full-scale remediation has been under way since 05/92.	Soil: petroleum, 100 mg/kg (EPA Recommended).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Active land tillage, moisture and nutrient control, seasonal monitoring for leachate below treatment zone.	None.
VIII	Public Service Company Denver, CO UST Lead (State)	Suzanne Stevenson (303)293-1511 Lisa Weer (303)331-4830	Ground water: petroleum. Volume: 12M gallons.	Full-scale remediation was completed 03/92. Started 06/89. Incurred cost: $500K.	Ground water: risk-based.	In situ treatment, hydrogen peroxide, combined bioprocess, nutrient addition. Aerobic conditions, indigenous organisms. Other technologies: chemical treatment.	A risk assessment has been submitted to the State of Colorado Health Department for review along with an application for closure.
VIII	Richey Airport Richey, MT CERCLA State Lead	Carol Fox (404)449-4067	Soil (vadose: sand, silt, loam, clay): pesticides (picloram (tordon), aldrin, dieldrin, endrin, methyloxychlordane, chlordane, α-BHC, γ-BHC, β-BHC, 4,4'-DDE, 4,4'-DDT, 4,4'-DDD, methyl parathion, ethyl parathion), herbicides (2,4-D, dicamba, atrazine), triallates (far-go).	Full-scale remediation is planned. Currently in predesign.	Not yet established.	In situ treatment. Ex situ treatment. Aerobic and anaerobic conditions, indigenous organisms.	None.
VIII	Union Pacific** Laramie, WY RCRA Lead (Federal)	Felix Flechas (303)293-1524	Soil / ground water: wood preserving (PAHs, PCP). Volume: 750K cubic yards.	Full-scale remediation has been under way since 09/91. Expected completion 01/96. Incurred cost: $50M. Total expected cost: $100M.	Not yet established.	In situ treatment, fixed film reactor. Ex situ land treatment. Aerobic conditions, indigenous organisms. Other technologies: chemical extraction, chemical treatment, in situ soil flushing, soil washing, thermal desorption. 50% of site under bioremediation.	Fluid delivery is not uniform, so bioremediation is not uniform.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
IX	Beale Air Force Base Marysville, CA Federal Facility Process 1	Sheri Rolfsness (916)634-2643	Soil (vadose silty clay): petroleum (diesel). Volume: 20K cubic yards.	Full-scale remediation has been under way since 07/92. Incurred cost: capital, $30K. Total expected cost: O&M, $6,000.	Soil (vadose): diesel, 50 mg/kg (state guidelines).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	Pilot-scale test demonstrated that bioremediation could work in silty-clay soil.
	Process 2		Soil (vadose silty clay): petroleum (gasoline, diesel), solvents. Volume: 10K cubic yards.	Pilot-scale studies have been under way since 10/92. Expected completion 10/93. Total expected costs: capital, $50K; O&M, $10K.	Soil (vadose): gasoline, 10 mg/kg; diesel, 50 mg/kg (state guidelines).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	Project will be a pilot-scale system, operating for one year.
	Process 3		Soil (vadose silty clay): petroleum (diesel, gasoline). Volume: 10K cubic yards.	Pilot-scale studies have been under way since 10/92. Expected completion 10/93. Total expected costs: capital, $50K; O&M, $10K.	Soil (vadose): diesel, 50 mg/kg; gasoline, 10 mg/kg (state guidelines).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	Project will be a pilot-scale test for one year.
	Process 4		Soil (vadose silty clay): petroleum (gasoline, diesel). Volume: 3,000 cubic yards.	Full-scale remediation has been under way since 11/92. Total expected costs: capital, $100K; O&M, $30K.	Soil (vadose): gasoline, 10 mg/kg; diesel, 50 mg/kg (state guidelines).	Ex situ treatment, pile. Aerobic conditions, indigenous organisms.	Biofilters to treat contaminated soil removed during Underground Storage Tank removal projects.
	Process 5		Soil (vadose silty clay): petroleum (diesel), lead. Volume: 10K cubic yards.	Pilot-scale studies have been under way since 10/92. Expected completion 10/93. Total expected costs: capital, $50K; O&M, $10K.	Soil (vadose): diesel, 50 mg/kg (state guidelines).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	Pilot-scale system to operate for one year.
	Process 6		Soil (vadose silty clay): petroleum (diesel, gasoline), solvents (TCE), lead. Volume: 100K cubic yards.	Full-scale remediation is planned. Currently in design. Expected start 06/93. Expected completion 06/96. Total expected costs: capital, $221K; O&M, $64K.	Soil (vadose): diesel, 50 mg/kg; gasoline, 10 mg/kg (state guidelines).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	None.
	Process 7		Soil (vadose silty clay): petroleum (diesel), lead. Volume: 10K cubic yards.	Full-scale remediation is planned. Currently in design. Expected start 10/93. Expected completion 10/96. Total expected costs: capital, $30K; O&M, $6,000.	Soil (vadose): diesel, 50 mg/kg (state guidelines).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	Process area recently discovered; little information available. Hope to install full-scale bioventing system.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
IX	BKK Landfill West Covina, CA RCRA Lead (Federal)	Carmen Santos (415)744-2037 Nancy Lindsay/Glenn Heyman (415)744-2044	Ground water: solvents (vinyl chloride, dichloromethane, chloroform, carbon tetrachloride, TCE, phenols, 1,2-dichloropropane), petroleum, arsenic, cadmium, chromium, cyanide, lead, mercury. Volume: 50K gallons per day.	Full-scale remediation has been under way since 01/87.	Not yet established.	Ex situ treatment, fluidized bed, continuous flow. Aerobic conditions. Other technologies: chemical treatment, may also treat landfill liquids to see if ground water not heavily contaminated can be stripped by an air stripping process. 100% of site under bioremediation.	Treatability study may be done on mixture of landfill leachate and ground water to see if system can treat. Plant will be expanded. Possible use of air strippers, which exist but are not being used.
IX	CALTRANS Lakeport, CA UST Lead (State)	Ken Smarkel (916)322-3910 John Wesnousky (915)324-1807	Soil: petroleum. Volume: 70 cubic yards.	Full-scale remediation was completed 01/89. Started 11/88.	Soil: petroleum, 100 mg/kg.	In situ land treatment.	Degradation rate was dependent upon the pile's porosity, water content, type of waste, soil, and bacterial consortium.
IX	Citrus Heights Irrigation Citrus Heights, CA UST Lead (State)	Ken Smarkel (916)322-3910 John Wesnousky (916)324-1807	Soil (silt): petroleum (diesel). Volume: 120 cubic yards.	Full-scale remediation was completed 08/89. Started 05/89.	Soil: diesel, 100 mg/kg.	Ex situ treatment, continuous flow. Aerobic conditions, indigenous organisms. 100% of site underwent bioremediation.	None.
IX	Converse/Montebello Corporation Yard** Montebello, CA UST Lead (State)	Paul Hadley (916)324-3823	Soil (vadose silt): petroleum (gas, diesel).	Laboratory-scale studies have been completed. Pilot-scale studies have been under way since 05/93. Expected completion 12/93.	Not yet established.	In situ treatment, bioventing, nutrient addition (nitrate and phosphate). Aerobic conditions, indigenous organisms. Other technologies: vacuum extraction. 10% of site under bioremediation.	None.
IX	CWX Freight Lines Santa Rosa, CA UST Lead (State)	Mark Berscheid (916)322-3294	Soil (vadose): petroleum (diesel). Volume: 600 cubic yards.	Full-scale remediation was completed 11/91. Started 10/90.	Not supplied.	Ex situ land treatment. Aerobic conditions, exogenous organisms. 100% of site underwent bioremediation.	None.
IX	Former Service Station Los Angeles, CA UST Lead (State)	Tony Palagyi (818)505-2701	Soil / ground water: petroleum. Volume: 3,000 cubic yards.	Full-scale remediation was completed 03/91. Started 11/88. Incurred cost: $1.6M.	Soil: TPH, 100 mg/kg. Ground water: benzene, 5 ppb.	In situ treatment, hydrogen peroxide, closed loop system, nutrient addition (water). Aerobic conditions, indigenous organisms. Other technologies: in situ soil flushing, vacuum extraction. 65% of site underwent bioremediation.	During channeling, overload reduced the reinjection process rate.
IX	Fort Ord Army Base Monterey, CA CERCLA Enforcement Lead	John Chestnut (415)744-2387 Vance Fong (415)744-2392	Soil / ground water: petroleum, solvents (MEK).	Pilot-scale studies are being conducted.	Ground water: MCLs.	In situ land treatment. Other technologies: pump and treat, carbon adsorption.	None.
IX	Gila Indian Reservation Bapchule, AZ CERCLA Fund Lead	Richard Martin (415)744-2288	Soil: pesticides (toxaphene, parathion). Volume: 100K cubic yards.	Full-scale remediation was completed 07/86. Started 01/84. Incurred cost: $700K.	Soil: background levels.	In situ land treatment. Aerobic and anaerobic conditions, indigenous organisms. 100% of site underwent bioremediation.	Toxaphene is very hard to break down. Materials handling was difficult.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
IX	Hamburg Ranch Merced County, CA CERCLA State Lead	Christine Holm (916)361-5703 Jack Grisanti (209)897-5873	Soil (vadose and saturated: loam, clay): pesticides (DDD, DDE, DDT, endosulfan, toxaphene, chlorfenvinphos, methidathion, monitor, nemacur, parathion-e, parathion-m).	Full-scale remediation is planned. Currently in predesign. Expected start 06/93. Expected completion 10/96.	Not yet established.	Bioremediation treatment not yet established.	This site is especially difficult because of the high degree of contamination and the amount of material involved. Excavation down to 1 ppm DDT, DDD, and DDE and 5 ppm toxaphene is now taking place. Much of this material will be disposed of at a Class 1 landfill, since it is characterized as non-RCRA waste. The remainder will be bioremediated on site.
IX	Harmon Field** Tulare County, CA CERCLA State Lead	Mike Pfister (209)297-3934	Soil (clay): pesticides (α-BHC, chlordane, difocol, endosulfan II, endrin, endrin aldehyde, heptachlor epoxide, 4,4'-DDE, 4,4'-DDT, 4,4'-TDE, methoxychlordane, toxaphene, heptachlor). Volume: 65 gallons.	Pilot-scale studies were completed 11/90. Started 05/90.	Not yet established.	Ex situ land treatment. Aerobic and anaerobic conditions, exogenous and indigenous organisms.	Tests were conducted on thirteen 5-gallon buckets of soil. Results showed that pesticides were not removed from the containers after 192 days of treatment. Due to the high variability of the data, however, it is unclear whether some degradation occurred. A larger scale study may be conducted to achieve statistically significant results.
IX	Hercules Incorporated Hercules, CA CERCLA State Lead	Tony Luan (916)322-6872	Soil: TNT, DNT, nitrobenzene. Volume: 1,500 cubic yards.	Full-scale bioremediation is not planned. Pilot-scale studies were completed 01/91. Started 01/89.	Soil: TNT, 30 mg/kg; DNT, 5 mg/kg; nitrobenzene, 5 mg/kg.	Ex situ land treatment. Aerobic conditions, indigenous organisms.	Pilot-scale project completed. Evaluating field study results.
IX	J.H. Baxter** Weed, CA CERCLA Enforcement Lead Process 1	Elizabeth Keicher (415)744-2361 Susan Warner (707)576-2220 Ed Cargile (916)255-3703	Sediments (sand, silt) / soil (sand, silt): wood preserving (tetrachlorophenol, PCP, PAHs), arsenic, chromium, copper, zinc. Volume: 21.9K cubic yards.	Full-scale remediation is planned. Currently in predesign. Expected start 12/94. Laboratory-scale and pilot-scale studies have been completed. Total expected costs: capital, $9.6M; O&M, $3.3M; total, $13M.	Soil: PCP, 17 mg/kg; carcinogenic PAHs, 0.51 mg/kg; noncarcinogenic PAHs, 0.15 mg/L (risk-based). Sediments: tetrachlorophenol, 1 mg/kg (risk-based).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Other technologies: cement fixation for soils contaminated with inorganics.	

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
	Process 2		Ground water: wood preserving (PAHs, PCP, dioxins), arsenic, chromium, copper, zinc. Volume: 150K gallons per day.	Full-scale remediation is planned. Currently in predesign. Expected start 12/94. Pilot-scale studies have been under way since 01/89. Total expected costs: capital, $4.3M; O&M, $13.1M; total, $17.4M.	Ground water: carcinogenic PAHs, 5 µg/L; noncarcinogenic PAHs, 5 µg/L; PCP, 2.2 µg/L; dioxins, 0.025 ppt (risk-based).	Ex situ treatment, fixed film, continuous flow. Aerobic conditions, indigenous organisms. Other technologies: chemical treatment.	Concern regarding effect of elevated metals on bioremediation process.
IX	JASCO** Mountain View, CA CERCLA Enforcement Lead	Rose Marie Caraway (415)744-2235	Soil (silt, clay) / ground water: solvents (1,1-DCA, 1,1-DCE, 1,2-DCE, 1,1,1-TCA, benzene, chloroethane, methyl ethyl ketone, acetone, methylene chloride, pentachlorophenol, tetrachloroethene, TCE, toluene, vinyl chloride, methanol, xylenes, ethylbenzene, 1,2-DCA), petroleum (diesel). Volume: 1,100 cubic yards.	Full-scale remediation is planned. Currently in design. Laboratory-scale studies were completed 11/91. Started 02/91. Incurred cost: $30K. Total expected costs: capital, $200K; O&M, $248K.	Soil: 1,1-DCA, 0.03 mg/kg; 1,1-DCE, 1 mg/kg; 1,1-DCA, 0.6 mg/kg; 1,2-DCE, 1 mg/kg; 1,1,1-TCA, 100 mg/kg; benzene, 0.3 mg/kg; chloroethane, 4,000 mg/kg; methyl ethyl ketone, 9 mg/kg; acetone, 30 mg/kg; methylene chloride, 0.2 mg/kg; pentachlorophenol, 200 mg/kg; tetrachloroethene, 7 mg/kg; TCE, 3 mg/kg; toluene, 1,000 mg/kg; vinyl chloride, 0.02 mg/kg; methanol, 200 mg/kg; xylenes, 2,000 mg/kg; diesel, 10K mg/kg; ethylbenzene, 3,000 mg/kg (potential migration to ground water). Ground water: acetone, 4,000 ppb; benzene, 1 ppb; 1,1-DCA, 5 ppb; 1,1-DCE, 6 ppb; 1,2-DCA, 0.5 ppb; methylene chloride, 150 ppb; pentachlorophenol, 1 ppb; toluene, 1 ppb; vinyl chloride, 0.5 ppb; TPH, 3,000 ppb; tetrachloroethene, 5 ppb.	Ex situ treatment, batch flow. Aerobic and anaerobic conditions. 100% of soil of site will undergo bioremediation.	The ROD selected an ex situ bioremediation process, which will combine aerobic and anaerobic treatments. The challenges at this site are (1) to minimize volatilization of contaminants during excavation, and (2) to balance the aerobic and anaerobic processes to treat the entire contaminated area. If cleanup levels are not achieved, contaminated material will be disposed of in a RCRA landfill.
IX	Koppers Company, Inc.** Oroville, CA CERCLA Enforcement Lead	Fred Schauffler (415)744-2365 Ed Cargile (916)255-3703	Soil (vadose: sand, clay, gravel, cobbles): wood preserving (PCP, PAHs, dioxins/furans), arsenic, chromium. Volume: 110K cubic yards.	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies were completed 01/93. Pilot-scale studies are planned. Expected completion 11/94. Total expected costs: capital, $4.5M; O&M, $7.7M.	Soil (vadose): PCP, 17 mg/kg (state ARAR); carcinogenic PAHs, 0.19 mg/kg (risk-based); dioxins/furans, 0.03 ppt (risk-based).	In situ treatment, nutrient addition. Aerobic conditions, indigenous organisms. Other technologies: soil washing, fixation of metal-contaminated soil, ground water treatment with carbon. 30% of site will undergo bioremediation.	None.
IX	Marine Corps Air/Ground Combat Center Twenty-Nine Palms, CA CERCLA Fund Lead	Ray Lukens (619)776-8958	Soil: petroleum (jet fuel, gasoline, diesel, aviation fluid, transmission fluid)	Full-scale remediation is planned. Currently in design.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	None.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
IX	Middle Mountain Silvex** Greenlee County, AZ Federal Facility	Robert M. Mandel (415)744-2290 Tim Steele (602)257-2335	Soil (vadose: silt, loam): pesticides (2,4,5-TP), herbicides (2,4-D, 2,4,5-T). Volume: 550 cubic yards.	Full-scale remediation was completed 09/92. Incurred cost: $30K. Total expected cost: $35K.	Soil (vadose): 2,4,5-TP, 50 mg/kg (state requirement).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Prepared bed with water and nutrients, periodic rototilling. Other technologies: photodegradation by ultraviolet sunlight at elevation of 9,000 ft above sea level. 100% of site underwent bioremediation.	None.
IX	Montrose Chemical Corporation of California Torrance, CA CERCLA Enforcement Lead	Nancy Woo (415)744-2394 Alice Geniro (310)590-4931 Steven Safferman (513)569-7350	Soil (vadose: silt, clay): pesticides (DDT), benzene, chlorobenzene, chloroform.	Laboratory-scale studies were completed 03/93. Started 09/92.	Not yet established.	Ex situ land treatment. Aerobic conditions, exogenous organisms. Other technologies: white rot fungus.	None.
IX	Moore Aviation Colusa, CA CERCLA State Lead	Christine Holm (916)361-5703 Al Williamson (916)753-9500	Soil (vadose: silt, loam): pesticides (DDE, endosulfan I & II, parathion, chlorpyrifos, disulfoton, propazine, atrazine, 2,4-D, 2,4,5-TP), bis(2-ethylhexyl)pthalat, phenols.	Full-scale remediation was completed 10/92. Started 09/91. Total expected cost: $35K.	Soil (vadose): DDE, 1 mg/kg; endosulfan I & II, 7.4 mg/kg; parathion, 3 mg/kg; chlorpyrifos, 2 mg/kg; disulfoton, 0.1 mg/kg; propazine, 0.14 mg/kg; atrazine, 0.03 mg/kg; 2,4-D, 1 mg/kg; 2,4,5-TP, 0.1 mg/kg (beneficial use water quality criteria).	Ex situ land treatment. Aerobic and anaerobic conditions, exogenous organisms.	Some problems with QA/QC on analyses; two independent labs are giving conflicting results. Endosulfans have been particularly recalcitrant.
IX	Naval Air Station Fallon Fallon, NV Federal Facility	Ron Hoeppel (805)952-1655 David Chesmore (702)687-5872 Steve Klauser (702)426-2785	Soil (vadose and saturated silt) / ground water: petroleum (jet fuel, p-xylene, naphthalene, 1-methyl naphthalene, n-butylbenzene), arsenic.	Pilot-scale studies have been under way since 10/92.	Not yet established.	In situ treatment, bioventing, oil/water separation, nutrient addition (soil). Aerobic conditions, indigenous organisms. Other technologies: vacuum extraction.	Problems obtaining a water discharge permit from the State of Nevada to discharge treated ground water to the NAS Fallon sewer system due to presence of natural arsenic in ground water.
IX	Naval Weapons Station—Seal Beach* Seal Beach, CA Research Facility	Carmen LeBron (805)982-1616	Ground water: petroleum.	Laboratory-scale studies are being conducted.	Not yet established.	In situ treatment. Aerobic and anaerobic conditions, indigenous organisms.	None.
IX	Oakland Chinatown* Oakland, CA UST Lead (State) Process 1 Process 2	Donald Smallbeck (415)899-8804	Soil (saturated sand) / ground water: petroleum. Volume: 10K cubic yards. Ground water: petroleum.	Full-scale remediation was completed 08/90. Started 03/89. Full-scale remediation was completed 08/90. Started 03/89.	Soil (saturated): BTEX, 100 mg/kg (RWQCB guidelines). Not supplied.	In situ treatment, hydrogen peroxide, nutrient addition (soil: ammonia nitrate, mono- and di-basic phosphates; water: ammonia nitrate, mono- and di-basic phosphates). Aerobic conditions, indigenous organisms. Ex situ treatment, completely mixed reactor, continuous flow. Aerobic conditions, indigenous organisms. Other technologies: carbon adsorption.	None. None.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
IX	Poly-Carb Wells, NV CERCLA Fund Lead	Robert M. Mandel (415)744-2290	Soil: wood preserving (cresol, phenols). Volume: 1,500 cubic yards.	Full-scale remediation was completed 09/88. Started 06/87. Incurred cost: $450K.	Soil: cresol, 10 mg/kg; phenols, 20 mg/kg (performance-based).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Other technologies: in situ soil flushing, in situ volatilization. 60% of site underwent bioremediation.	None.
IX	Protek Carson City, CA UST Lead (State)	Ken Smarkel (916)322-3910	Soil: petroleum. Volume: 700 cubic yards.	Full-scale remediation was completed 12/89. Started 08/88.	Soil: petroleum, 10 mg/kg.	Ex situ land treatment. 100% of site underwent bioremediation.	The control cell, which did not receive any nutrient supplements, proprietary inoculum, or the benefit of rigorous aeration, showed contaminant level reductions equal to those of the treatment cells.
IX	San Diego Gas and Electric** San Diego, CA UST Lead (Federal)	Paul Hadley (916)324-3823	Soil (sand): petroleum (gasoline). Volume: 1,200 cubic yards.	Full-scale remediation was completed 04/93. Started 10/89.	Not supplied.	In situ treatment. Anaerobic conditions, indigenous organisms. 100% of site underwent bioremediation.	None.
IX	Seaside High School Seaside, CA UST Lead (State)	Dick Ericksson (916)322-7046	Soil: petroleum (diesel). Volume: 100 cubic yards.	Full-scale remediation was completed 06/88.	Soil: diesel, 500 mg/kg.	Ex situ land treatment. Aerobic conditions, indigenous organisms. 100% of site underwent bioremediation.	Diesel fuel concentrations were reduced below 1,000 mg/kg with multiple applications of fertilizer, moisture, and tilling. Indigenous bacteria effected the reduction in fuel concentrations.
IX	SEGS Solar Project Kramer Junction, CA State Lead	Bruce LaBelle (916)324-2958	Soil: biphenyl, diphenyl ether.	Full-scale remediation has been under way since 07/90.	Soil: biphenyl, 1,000 mg/kg; diphenyl ether, 1,000 mg/kg.	Ex situ treatment, pile.	None.
IX	Solvent Service San Jose, CA CERCLA State Lead	Bruce Wolf (510)286-0787 Marie Lacey (415)744-2234	Ground water: solvents (1,2-DCE, cis-1,2-DCE, trans-1,2-DCE, ethylbenzene, 1,1,1-TCA, freon 113, benzene, acetone, 1,1-DCE, naphthalene).	Full-scale remediation has been under way since 01/91. Incurred cost: $399K. Total expected cost: $844K.	Ground water: 1,2-DCE, 5 µg/L; cis-1,2-DCE, 6 µg/L; trans-1,2-DCE, 10 µg/L; ethylbenzene, 400 µg/L; 1,1,1-TCA, 200 µg/L; freon 113, 1,200 µg/L; benzene, 0.7 µg/L; acetone, 400 µg/L; 1,1-DCE, 1 µg/L; naphthalene, 2,000 µg/L.	Ex situ treatment, fixed film, continuous flow. Anaerobic conditions, exogenous organisms. Other technologies: soil washing, vacuum extraction, steam enhancement. 100% of site under bioremediation.	Had difficulty obtaining a permit for bioremediation.
IX	Southern Pacific Transportation Company Roseville, CA CERCLA State Lead	David Wright (916)332-3910	Soil: petroleum. Volume: 240 tons.	Full-scale remediation was completed 01/91. Started 11/90. Incurred cost: $310K.	Soil: petroleum, 5,000 mg/kg.	Ex situ land treatment.	None.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
X	East 15th Street Service Station Anchorage, AK UST Lead (State)	Tony Palagyi (818)505-2701	Soil: petroleum (TPH diesel). Volume: 1,500 cubic yards.	Full-scale remediation has been under way since 06/92. Incurred cost: $75K. Total expected cost: $200K.	Soil: TPH diesel, 100 mg/kg (regulatory guidelines).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. Other technologies: vacuum extraction. 20% of site under bioremediation.	Winter weather has been an obstacle to bioremediation.
X	Fairchild Air Force Base Spokane, WA Federal Facility Process 1	Thomas Smiley (509)247-2313 William Harris (206)438-3070 Diane Wulf (509)247-2313	Soil (vadose and saturated silt) / ground water: solvents (TCE).	Pilot-scale studies are planned. Expected start 01/95. Total expected costs: capital, $5M; O&M, $50K.	Ground water: TCE, 5 µg/L. Soil (vadose and saturated): TCE, 0.5 mg/kg.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. Other technologies: vacuum extraction.	None.
	Process 2		Soil (vadose silt): petroleum, solvents (TCE).	Pilot-scale studies have been under way since 04/93.	Soil (vadose): benzene, 0.5 mg/kg; TPH, 200 mg/kg; TCE, 0.5 mg/kg.	In situ treatment, bioventing, nutrient addition. Aerobic conditions, indigenous organisms.	None.
	Process 3		Soil (vadose silt): petroleum.	Pilot-scale studies have been under way since 04/93.	Soil (vadose): TPH, 200 mg/kg.	In situ treatment, bioventing, nutrient addition. Aerobic conditions, indigenous organisms.	None.
X	J.H. Baxter Company Renton, WA State Lead	Gail Colburn (206)649-7058 Ching-Pi Wang (206)649-7134	Sediments (sand, silt) / sludge / soil (vadose and saturated complex mixture) / ground water: wood preserving (PAHs, PCP, TPH). Volume: 20K cubic yards.	Full-scale remediation is planned. Currently in design. Expected start 02/94. Expected completion 10/98. Laboratory-scale studies were completed 11/92. Started 08/92.	Ground water: risk-based. Soil (vadose and saturated): risk-based.	Ex situ land treatment. Aerobic conditions, exogenous and indigenous organisms.	May not be able to meet RCRA treatability standards for land disposal. Benzo(a)pyrene appears the most difficult compound to degrade. Other results are very good: 40% to 90% removals on individual PAHs. Those bins experiencing drainage problems had reduced rates of bioremediation. Properly draining bins showed 90% reductions.
X	Unocal—Seattle Marketing Terminal Seattle, WA State Toxics, PRP Lead	Nnamdi Madakor (206)649-7112	Soil: petroleum. Volume: 34K cubic yards.	Full-scale remediation has been completed. Incurred cost: $3.5M.	Not supplied.	Ex situ land treatment. 40% of site underwent bioremediation.	Bioremediation has been successful for treating soils in the upper yard. Soils were excavated, treated, and disposed of at the Coal Creek Landfill. Treatability studies have revealed that solid-phase bioremediation is ineffective at treating lower yard soils which are contaminated with heavier hydrocarbons. The state is discussing an amendment to the Consent Decree to accommodate alternative technologies.

* Indicates a new site.
** Indicates that the site has been updated.

Shading indicates a non-CERCLA site.

FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
X	Utah Power and Light Idaho Falls, ID RCRA Lead (state)	Andrew Pentony (208)334-5898 Randy Steger (208)334-5898	Soil (vadose): wood preserving (PAHs).	Pilot-scale studies were completed 07/91.	Soil (vadose): PAHs, 50 µg/kg (permit standards).	In situ land treatment. Aerobic conditions, exogenous organisms. Other technologies: pump and treat. 33% of site underwent bioremediation.	No monitoring of addition of water or mixing and drying. No indications of dilution or volatilization. Tests were determined to be unsuccessful.
X	Wyckoff Eagle Harbor Puget Sound, WA CERCLA Enforcement Lead	Rene Fuentes (206)553-1599 Sally Martin (206)553-2102	Ground water: wood preserving (PCP, PAHs).	Full-scale remediation has been under way since 01/90.	Ground water: PCP, 6 µg/L; PAHs, 20 µg/L (water quality criteria).	Ex situ treatment, activated sludge, fixed film, continuous flow. Aerobic attached growth process in series with aeration tank, clarifier, and biological sludge digester, possible sludge and soil remediation. Aerobic conditions, exogenous organisms. Other technologies: oil/water separation, carbon polishing.	Lower TOC than expected during design. Periodic PCP toxicity.

GLOSSARY OF BIOREMEDIATION TERMS

Growth Conditions

Aerobic-In the presence of oxygen.

Anaerobic-In the absence of oxygen.

Source of Microorganisms

Indigenous-Occurring naturally at a site.

Exogenous-Not native to a site.

Treatment in a Reactor

Activated Sludge-The biomass is suspended in liquid, captured in a clarifier, and recycled to the reactor; the contact time between the waste and the biomass is controlled by wasting excess biomass.

Extended Aeration-The biomass is suspended in liquid, captured in the clarifier, and recycled to the reactor; a long contact time is created by enlarging the aeration basin.

Contact Stabilization-The waste contacts the biomass suspended in liquid in the first aeration tank and contaminants are adsorbed to the clarified biomass; then they are digested in the second aeration tank.

Fixed Film-Biomass is retained in the system by using a static support media.

Fluidized Bed-Bacteria is attached to a support media, which is fluidized in the reactor.

Sequencing Batch Reactor-This self-contained treatment system incorporates equalization, aeration, and clarification using a draw and fill approach on wastewater sludges.

Slurry Reactor-Contaminants are treated in a soil slurry (a thin mixture of soil and water) with nutrients and oxygen added as needed; water and soil must be separated after treatment, but clean soil is left on site.

Treatment Outside of a Reactor

Aerated Lagoon-The biomass is kept suspended in liquid with aeration.

Land Treatment-Waste is applied onto or incorporated into the soil surface in a facility. Contaminants are treated with microorganisms typically indigenous to the existing soil matrix; nutrients, moisture, and oxygen can be added to optimize growth conditions. If the waste remains at the facility after closure, the land treatment facility becomes a disposal facility.

Pile-This method refers to any noncontainerized accumulation of solid, nonflowing waste being treated or stored.

Bioventing-Air is injected into contaminated soil at rates low enough to increase soil oxygen concentrations and stimulate indigenous microbial activity without releasing volatile emissions.

In Situ Treatment-Biodegradable contaminants are treated by microorganisms within the environment in which they are found. Most commonly, this process utilizes aerobic processes and involves delivery of oxygen or other electron acceptors and other appropriate amendments.

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Update on the Bioremediation Field Initiative

(Continued from page 1)

At the Libby Ground Water Superfund site, all field evaluation sampling has been completed. Technical reports on the performance of the two fixed-film bioreactors and the land treatment units will be undergoing peer review this summer. Laboratory tests are being conducted on aquifer cores to determine the presence and metabolic capability of indigenous microbes and evaluate the effects of temperature, oxygen, and nutrients. Ground water sampling was performed during March 1993 to help evaluate the role of preferential flow paths within the aquifer. Discrete samples were obtained over the length of the well screens from monitoring wells within the aquifer where hydrogen peroxide and nutrients were introduced.

The Air Force constructed a new test plot at Eielson Air Force Base in September 1992 to evaluate soil warming using buried heat tape. Results from the new test plot showed temperatures ranging from 10 to 12°C. The plot heated by warm water showed temperatures ranging from 15 to 16°C; the plot using plastic mulching achieved temperatures of only 2 to 3°C; and the unheated control plot stayed at 0°C. A January 1993 respirometry test on the test and control plots confirmed that rates of degradation decreased with decreasing temperature.

At Hill Air Force Base, a helium tracer study was conducted from December 1992 through January 1993 to determine the heterogeneity of air movement through the site. Data from the study currently are being evaluated. Injection rates now are being maintained at a low flow rate of 45 ft^3/min. The next respiration test will be conducted in June 1993.

The field demonstration at the Escambia Wood Preserving site–Brookhaven has been completed. Data from the demonstration currently are being analyzed.

At the Reilly Tar and Chemical Corporation Superfund site, installation of two adjacent 50-ft by 50-ft plots was completed in November 1992. The first is a test plot equipped with one 10-ft-deep bioventing well; the second is a control plot, which is not biovented. Sampling at time-zero in November 1992 indicated that, due to the pervious soil at the site, injected air was migrating from the test plot 125 to 180 ft into the control plot. A 10-ft-deep bentonite slurry wall was constructed across the near wall of the control plot. The slurry wall has prevented any further unwanted aeration of the control plot. A 3-year evaluation program was initiated in November 1992 with the time-zero sampling. In situ respiration tests will be conducted several times each year to determine oxygen utilization and carbon dioxide evolution rates, which can be used to estimate biodegradation rates. Soil core analyses will be performed periodically to verify the disappearance of polycyclic aromatic hydrocarbons (PAHs). Because of the strong partitioning of PAHs to soil, long-term bioventing probably will be necessary to complete remediation of this site. The target PAH removal rate for the 3-year project is 30 percent. Based on this rate, full-scale remediation would require 10 to 15 years.

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