EPA/540/N-92/004 No. 7 October 1992

EPA
U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Office of Research and Development

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. 36); 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. 9).

Eight sites have been selected for field evaluation of bioremediation: Libby Superfund site, Libby, Montana; Park City Pipeline, Park City, Kansas; Allied Signal Superfund site, St. Joseph, Michigan; Eielson Air Force Base, Alaska; Hill Air Force Base, Utah; Brookhaven Superfund site, Brookhaven, Mississippi; Public Service, Denver, Colorado; and Reilly Tar and Chemical Corporation, St. Louis Park, Minnesota (see article on this page).

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In This Issue

Field Initiative Begins Bioventing of PAHs at Reilly Tar Site

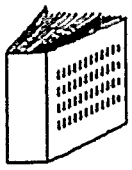
The Bioremediation Field Initiative, in cooperation with the Superfund Innovative Technology Evaluation demonstration program and the Risk Reduction Engineering Laboratory's Biosystems Program, has undertaken a pilot-scale field project to test bioventing of polycyclic aromatic hydrocarbons (PAHs) in soil. Bioventing has proven effective at remediating lightweight petroleum distillates such as JP-4 jet fuel; this will be the first test of bioventing's effectiveness for remediation of larger molecular weight hydrocarbons.

The project will take place in St. Louis Park, Minnesota, at the former site of Reilly Tar and Chemical Corporation's coal tar distillation and wood preserving plant. From 1917 to 1972, wastewater discharges and dumping from this plant contaminated about 80 acres of soil and the underlying ground water with wood preserving wastes. In 1978, the Minnesota Department of Health discovered significant concentrations of PAHs in six municipal drinking water wells neighboring the Reilly Tar plant. St. Louis Park is currently pumping and treating the contaminated ground-water plume, but without an effort to control the source of PAHs, pumping and treating will be necessary for several hundred years.

Treatability studies were conducted at the site in August 1992. These studies revealed PAH contamination in sandy vadose soil ranging from 2 to 10 feet below the surface. The studies also indicated that the soil's air permeability and microbial activity are appropriate for bioventing. Installation of bioventing wells and baseline soil sampling are scheduled for November 1992.

The demonstration project is expected to last 3 years, at which point it is estimated that soil core samples will show a 30 percent reduction in PAH levels. If bioventing successfully remediates PAHs at this rate, complete remediation of the site will take 10 to 15 years.

For more information, contact Paul McCauley at 513-569-7444 or Dick Brenner at 513-569-7657.



Addressing Land Disposal Restrictions in Biotreatment

On August 18, 1992, the Land Disposal Restrictions (LDRs) for Newly Listed Wastes and Contaminated Debris Rule was promulgated. This is Phase 1 of a three-phased regulation promulgating treatment standards for newly listed hazardous wastes and designating technologies for the treatment of contaminated soil and debris. Phase 2, covering soil and adding standards for more newly listed wastes, is scheduled to be issued in May 1993. Phase 3, adding standards for the remaining newly listed wastes, is scheduled to be issued in March 1994. The LDRs will have a significant impact at sites where bioremediation is being used to clean up hazardous wastes prior to land disposal.

The purpose of the LDRs is to prevent land disposal of untreated hazardous waste. Accordingly, two conditions must be met for the LDRs to apply: (1) the waste must be a Resource Conservation and Recovery Act (RCRA) hazardous waste, and (2) the waste must be destined for land disposal. The regulation defines land disposal as any placement of a hazardous material in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, or underground cave. Thus, in situ bioremediation is not covered by the LDRs. The LDRs become applicable as soon as hazardous materials are excavated, even if subsequently they are returned to their original site or moved to another contaminated site.

As in the case of previous LDR rulemakings, a national capacity variance has been provided to extend the effective date of the LDRs until treatment capacity is available. At that point, the authority for implementing the LDRs will rest with EPA until states receive authorization for the LDR provisions. In some cases, the state regulations may be more stringent than the federal requirements, so EPA cautions biotreaters to review existing state regulations prior to treatment of hazardous waste.

Newly Listed Wastes

The original LDRs, enacted in 1984, required EPA to promulgate treatment standards by May 8, 1990, for all wastes that exhibited hazardous waste characteristics or were listed as hazardous as of 1984, a task EPA completed through five rulemakings from 1986 to 1990. The three phases of the new LDRs will supplement these standards and specify standards for several wastes listed since 1984, including petroleum-refining and wood preserving wastes, which are frequently candidates for bioremediation.

Under the new regulation, each newly listed waste is assigned one of two types of treatment standards. Some wastes have *concentration-based* standards,

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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.

Air Force Launches Bioventing Initiative

In May, the U.S. Air Force launched an extensive program to examine bioventing as a remedial technique at contaminated Air Force Base (AFB) sites across the country. Bioventing is a promising new technology that promotes aerobic degradation of contaminants in soil by direct injection or vacuum extraction of air. The Air Force Bioventing Initiative targets 55 sites with jet fuel, diesel fuel, or fuel oil in soil.

In selecting sites for the initiative, the Air Force looked for characteristics appropriate for bioventing, such as deep vadose soil, heavy hydrocarbon contamination, and high air permeability. Air Force project coordinator Major Ross Miller reports that the chosen sites represent a wide range of depths to ground water, hydrocarbon concentrations, and soil textures.

Short-term testing began at several sites in May to determine the air permeability and in situ respiration of the soil. At most sites, the test system consists of a single vent well with screening in the unsaturated zone and three soil-gas monitoring wells at various distances from the vent well. By injecting air through the vent well and measuring pressure changes in the soil-gas monitoring wells, researchers establish the soil's air permeability and the radius of influence of the injection well. The rate of biodegradation in the soil is then determined by temporarily shutting down air injection to the vent well and measuring the rate of in situ oxygen respiration in the monitoring wells.

Where short-term tests reveal high air permeability and degradation rates, the Air Force will initiate long-term bioventing tests. The requisite apparatus and an operation manual will be provided at each site so that base personnel can monitor the progress of long-term testing for 2 or 3 years. At small sites, long-term testing may well complete the necessary remediation. At large sites, data from long-term testing will be used to design full-scale bioventing systems. Preliminary testing has been completed and full-scale systems installed at Beale, Eglin, Eielson, F.E. Warren, Hill, Galena, Newark, Offutt, and Plattsburgh Air Force Bases.

The Air Force's decision to examine bioventing on such a large scale was prompted by a successful demonstration of the technology at Tyndall AFB in Florida. At this site, bioventing was coupled with moisture addition to remediate jet fuel in sandy unsaturated soil. Before bioventing was initiated, hydrocarbon concentrations ranged from 30 to 23,000 mg/kg. After 7 months of treatment, 32 kg of hydrocarbons had biodegraded from one treatment cell. It was estimated, however, that stricter air flow management could have resulted in more degradation and less volatilization of contaminants. Similar projects are being undertaken in cooperation with EPA's Bioremediation Field Initiative at Hill AFB in Utah and at Eielson AFB in Alaska.

The Tyndall AFB project demonstrated several advantages of bioventing over alternative oxygen delivery systems. First, bioventing uses a low-pressure air flow, so vapor-phase hydrocarbons that are volatilized during the venting process are biodegraded before they escape from the soil. Thus, bioventing eliminates the expensive off-gas treatment step, reducing remediation costs by 50 percent or more. Second, bioventing appears to be the only cost-effective, in situ technique for remediating nonvolatile or low volatile hydrocarbons like fuel oil and diesel. Third, bioventing can be used to treat contaminants in areas where structures and activities cannot be disturbed, because air injection wells, air blowers, and soil-gas monitoring wells form a relatively noninvasive apparatus.

There are currently over 4,300 documented Air Force disposal sites requiring investigation and possible remediation. At least half of these sites are contaminated with petroleum hydrocarbons. If the Air Force Bioventing Initiative is a success, bioventing could play a significant role in achieving the Air Force's goal of initiating cleanup of all sites by 2000.

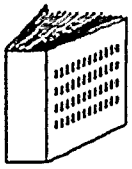
For more information on the Air Force Bioventing Initiative, contact Major Ross Miller of the Air Force Center for Environmental Excellence at 512-536-4331.

Bioremediation Field Initiative Holds Open House at Eielson AFB

Eielson Air Force Base in Fairbanks, Alaska, site of a field study of in situ bioventing and soil warming methods, will host an open house in January 1993. The bioventing project, sponsored jointly by EPA's Bioremediation Field Initiative and the U.S. Air Force, has demonstrated successful year round bioremediation in both heated and unheated soils, despite the harsh winter climate.

The open house will include a formal presentation of results and a tour of the site in operation. Project scientists from the EPA Risk Reduction Engineering Laboratory, Air Force Civil Engineering Support Agency, Air Force Center for Environmental Excellence, Eielson AFB, and Battelle Laboratories will attend.

Contact Gregory Sayles of EPA at 513-569-7607 to receive the final dates and agenda for the open house.



Permitting Bioremediation for PCB Disposal: Part 2, Commercial Operating Permits

This is the second of two articles on permitting the bioremediation of polychlorinated biphenyls (PCBs) under the Toxic Substances Control Act (TSCA). The first, on research and development (R&D) permits, appeared in issue No. 6 of *Bioremediation in the Field.*

To obtain a commercial operating permit for the bioremediation of PCBs, an applicant must prove that the process destroys PCBs as reliably as incineration without producing toxic by-products or emissions. To date, all of the permits issued by EPA Headquarters for the bioremediation of PCBs have been for research and development; none has been issued for commercial operation. Nonetheless, the Agency has been developing guidelines for the permitting procedure.

EPA requires evidence that PCB molecules have been* biologically *degraded.

EPA will permit only processes that a company can demonstrate to be effective—a threefold challenge. First, since the effectiveness of bioremediation varies widely from site to site, EPA requires visual inspection of the site and laboratory studies to determine if the treatment is suitable for the site in question. Second, since techniques that appear promising in the lab may fail in the field, EPA further requires pilot-scale studies at the site. Finally, once a technique has been shown to reduce contaminant levels at the site, EPA requires evidence that PCB molecules have been *biologically* degraded—not attenuated by nonbiological processes.

Determining the biological degradation of PCBs in soil is a complex undertaking, because PCB molecules penetrate soil and can be sorbed, volatilized, transported, and attenuated by abiotic reactions. EPA feels a conservative approach is needed to make this determination. One such approach is outlined in a recent article by Eugene Madsen in *Environmental Science and Technology.* Madsen cites five types of evidence necessary to demonstrate in situ bioremediation of PCBs:

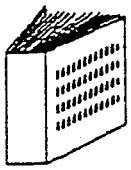
- In situ recording of greater contaminant losses from biodegradation than would be expected from abiotic degradation
- Assays with laboratory-incubated flasks demonstrating the presence of metabolically adapted microorganisms
- In situ detection of unique microbial metabolites
- In situ detection of increased protozoan populations preying on contaminant-fed bacterial populations
- In situ detection of decreased ratios of biodegradable congeners to nonbiodegradable congeners

Madsen's method is rigorous, but rigor is needed to ensure that bioremediation has actually taken place, even for processes that appear to be effective.

The length of time required to permit bioremediation for commercial operation has yet to be determined. EPA Headquarters requires three successful runs before issuing a permit for a nonbiological process. Because bioremediation is a lengthy process, three runs may not be a practical requirement for this technology. Instead, the Agency is considering requiring 3 years of successful research and development before issuing a commercial permit. EPA welcomes applications for R&D permits, which are usually issued for 1 year. This year may be seen as a trial period designed to demonstrate whether the technology will be commercially reliable in any situation at any site.

EPA feels that the permitting process is justifiably cautious because the technology for bioremediation of PCBs is still in its infancy. The public perceives bioremediation as a glamorous new technology that will soon solve hazardous waste problems in soil, water, and air. Bioremediation shows obvious promise, but if permitted processes fail to perform, the public may become disillusioned with the entire bioremediation industry.

For more information on TSCA permitting for PCB disposal, contact Joan Blake of EPA's Office of Pollution Prevention and Toxics at 202-260-6236.



EPA Issues Report on Bioremediation Case Study Collection

The U.S. Environmental Protection Agency's (EPA) Office of Research and Development (ORD) recently released *Bioremediation Case Study Collection: 1991 Augmentation of the Alternative Treatment Technology Information Center (ATTIC)*. This report documents the results of a 1991 effort by the Data Identification/Collection Subcommittee of EPA's Bioremediation Action Committee (BAC) to increase the number of bioremediation case studies in ORD's ATTIC data base. This data base includes information on biological technologies, as well as thermal, solidification/stabilization, chemical, and physical technologies.

In total, BAC collected information on 240 sites where private companies are using bioremediation to clean up hazardous contaminants. This information ranged in detail from brief summaries to 30-page reports. BAC determined that 132 sites had sufficient information to meet ATTIC database acceptance criteria. ORD's report presents statistics on the number of case studies accepted by scale of project, contaminants treated, media treated, and treatment methods. Though not comprehensive, the report suggests a profile of current bioremediation activities in the field.

Over 65 percent of the case studies describe full-scale projects, 20 percent describe pilot-scale projects, and 26 percent describe laboratory-scale projects. Petroleum was the most common contaminant, undergoing treatment at 56 percent of the sites; wood preservatives were second at about 11 percent, followed by solvents at 8 percent. Soil was the sole medium treated at 46 percent of the sites, soil and ground water were treated jointly at 23 percent of the sites, and ground water alone was treated at 16 percent of the sites. Over 60 percent of the sites remediating soil employed solid phase/land treatment, in which soil was spread over a prepared area and treated to optimize conditions for biodegradation. A bioreactor was used at 42 percent of the sites reporting ground-water treatment. At those sites where a bioreactor was not used, ground water was typically pumped to the surface, amended with nutrients, and reinjected. Twenty-nine percent of the case studies reported the use of additional technologies to supplement bioremediation.

EPA will be updating and expanding this data base with information supplied by vendors, contractors, and industry. Information will be sent to specific companies and a general notice will appear in a future issue of this bulletin.

To order a copy of the 31-page report, write to ORD Publications Office, Center for Environmental Research Information, 26 West Martin Luther King Drive, Cincinnati, OH 45268-1072, or call 513-569-7562. To order hard copy of all 132 case studies, write to Dr. Curtis Harlin, Office of Research and Development, U.S. EPA, 401 M Street SW., Washington, DC 20460, or call Dr. Harlin at 202-260-9642. For more information on the ATTIC data base, contact the systems operator at 301-670-6294.

Companies Included in the Report

Participating Company*	Location of Coordinating Office
ABB Environmental	Wakefield, MA
CET Environmental Services	Long Beach, CA
ECOVA Corporation	Redmond, WA
Environmental Remediation, Inc.	Baton Rouge, LA
Groundwater Technology, Inc.	Concord, CA
IT Corporation	Knoxville, TN
OHM Corporation	Walnut Creek, CA
Remediation Technologies, Inc.	Chapel Hill, NC
Roy F. Weston, Inc.	West Chester, PA
Woodward-Clyde	San Diego, CA

*Participating companies submitted information voluntarily.

Technology Innovation Office Releases *Groundwater Currents*

Groundwater Currents, the latest technology newsletter from the Technology Innovation Office, is now available. *Groundwater Currents* reports on the development and application of innovative in situ and ex situ groundwater remediation technologies. Articles also will include innovative monitoring technologies and analysis systems, references to new regulations that impact ground-water remediation, highlights on current issues such as dense nonaqueous phase liquids (DNAPLs), and information on conferences and publications. To be included on the permanent mailing list, send a fax request to the EPA Publications and Information Center (EPIC) at 513-891-6685, or send a mail request to EPIC, 11029 Kenwood Road, Building 5, Cincinnati, Ohio 45242.

EPA Bioremediation Publications

To order EPA documents, call 513-569-7562. For NTIS documents, call 1-800-553-6847.

Characterizing Heterogeneous Wastes	NTIS PB92-216894
Fundamentals of Ground-Water Modeling	EPA/540/S-92/005
A Study to Determine the Feasibility of Using a Ground Penetrating Radar	EPA/600/R-92/089
Bioremediation of Hazardous Waste	EPA/600/R-92/126
Methodologies for Evaluating In Situ Bioremediation of Chlorinated Solvents	NTIS PB92-146943
TCE Removal from Contaminated Soil and Ground Water	EPA/540/S-92/002
In Situ Bioremediation of Contaminated Ground Water	EPA/540-S-92/003
Technology Evaluation Report: Biological Treatment of Wood Preserving Site Ground Water by Biotrol, Inc.	NTIS PB92-110048
Applications Analysis Report: Biological Treatment of Wood Preserving Site Ground Water by Biotrol, Inc.	EPA/540/A5-91/001
Microbial Removal of Halogenated Methanes, Ethanes, and Ethylenes in an Aerobic Soil Exposed to Methane (Journal Version)	NTIS PB89-103196
Sequential Reductive Dehalogenation of Chloranilines by Microorganisms from a Methanogenic Aquifer	NTIS PB90-117219
Creosote-Contaminated Sites	NTIS PB90-129552
Action of a Fluoranthene-Utilizing Bacterial Community on Polycyclic Aromatic Hydrocarbon Components of Creosote	NTIS PB90-245721
Assessing Detoxification and Degradation of Wood Preserving and Petroleum Wastes in Contaminated Soil	NTIS PB90-245275
Alaskan Oil Spill Bioremediation Project	NTIS PB90-216466
Laboratory Studies Evaluating the Enhanced Biodegradation of Weathered Crude Oil Components through the Application of Nutrients	NTIS PB90-264011
Total Organic Carbon Determinations in Natural and Contaminated Aquifer Materials	NTIS PB91-129205
Anaerobic In Situ Treatment of Chlorinated Ethenes	NTIS PB91-137067
In Situ Bioremediation of Spills from Underground Storage Tanks: New Approaches for Site Characterization, Project Design, and Evaluation of Performance	NTIS PB89-219976
Comparison of Methods to Determine Oxygen Demand for Bioremediation of a Fuel-Contaminated Aquifer	NTIS PB89-207351
Available Models for Estimating Emissions Resulting from Bioremediation Processes: A Review	NTIS PB90-228610
Role of Microorganisms in the Bioremediation of the Oil Spill in Prince Willliam Sound, Alaska	NTIS PB90-263070
Approach to Bioremediation of Contaminated Soil	NTIS PB91-116152
Protocol for Testing Bioremediation Products Against Weathered Alaskan Crude Oil	NTIS PB91-137018
Reductive Dehalogenation: A Subsurface Bioremediation Process	NTIS PB91-144873
Field Evaluation of In Situ Biodegradation for Aquifer Restoration	NTIS PB88-130257
Alternative Biological Treatment Processes for Remediation of Creosote-Contaminated Materials: Bench-Scale Treatability Studies	NTIS PB91-179085
Nitrate for Biorestoration of an Aquifer Contaminated with Jet Fuel	NTIS PB91-164285
Movement of Bacteria through Soil and Aquifer Sand	NTIS PB91-164277
Selection of Nutrients to Enhance Biodegradation for the Remediation of Oil Spilled on Beaches	NTIS PB91-233304
Effect of Sodium Chloride on Transport of Bacteria in a Saturated Aquifer Material	NTIS PB92-110428
Oil Spill Cleanup	NTIS PB92-110469
Enhanced Bioremediation Utilizing Hydrogen Peroxide as a Supplemental Source of Oxygen: A Laboratory and Field Study	NTIS PB90-183435
The Federal Technology Transfer Act: Opportunities for Cooperative Biosystems Research and Development with U.S. EPA	CERI-90-114
Bioremediation of Contaminated Surface Soil	NTIS PB90-164047
Enhanced Bioremediation Utilizing Hydrogen Peroxide as a Supplemental Source of Oxygen: A Laboratory and Field Study	NTIS PB90-183435
Guide for Conducting Treatability Studies under CERCLA, Aerobic Biodegradation Remedy Screenings	NTIS PB92-109065
Interactive Simulation of the Fate of Hazardous Chemicals during Land Treatment of Oily Wastes: Ritz User's Guide	NTIS PB88-195540
In Situ Bioremediation of Spills from Underground Storage Tanks	NTIS PB89-219976
Microbial Decomposition of Chlorinated Aromatic Compounds	EPA/600/2-86/090
Removal of Volatile Aliphatic Hydrocarbons in a Soil Bioreactor	NTIS PB88-180393
Transformation of Halogenated Aliphatic Compounds	NTIS PB88-170568
Understanding Bioremediation: A Guidebook for Citizens	EPA/540/2-91/002

Conference Highlights

Fourth Forum on Innovative Hazardous Waste Treatment Technologies: Domestic and International

This forum, sponsored by U.S. EPA's Technology Innovation Office and Risk Reduction Engineering Laboratory, and the California Environmental Protection Agency, will be held November 17-19, 1992, at the Westin, St. Francis, San Francisco, CA. Using technical paper and poster presentations, this 3-day conference will introduce and highlight innovative treatment technologies having actual performance results. It will showcase the results of selected international technologies, the U.S. EPA Superfund Innovative Technology Evaluation (SITE) Program technologies, the CAL-EPA field demonstration program, and case studies from those using innovative technologies. The overall objective is to increase awareness in the user community of technologies ready for application at cleanup sites.

For further information, contact SAIC, Technology Transfer Department, 501 Office Center Drive, Suite 420, Ft. Washington, PA 19034, 215-542-1200 (fax: 215-542-8567).

Second International Symposium on In Situ and Onsite Bioreclamation

This symposium, sponsored by Battelle and supported by EPA, will be held at the Sheraton Harbor Island Hotel, San Diego Bay, CA, April 5-9, 1993. Researchers, engineers, site managers, regulatory agents, consultants, and vendors should all benefit from this opportunity to exchange information on case histories of field operations, examine ongoing research programs, and investigate public and regulatory acceptance of bioremediation technologies from a global perspective. More than 240 platform presentations and more than 60 poster presentations have been scheduled. Session titles include:

- Chlorinated Aromatics and PCBs
- Anaerobic and Aerobic Biodegradation of Chlorinated Solvents
- Explosives and Nitroaromatics
- Cold Region Applications
- Marine Spills
- Polycyclic Aromatic Hydrocarbons
- Bioventing, Air Sparging, and Related Technologies
- Land Treatment
- Vapor Phase Bioreactors
- Aqueous Phase Bioreactors
- Fungal Technologies
- Soil Bioreactors
- Characterization and Development of Microbial Populations and Strains
- Non-Indigenous Organisms
- Hydrogeological Considerations
- Process Monitoring and Verification
- Surfactant- and Enzyme-Aided Bioremediation
- Alternative Electron Acceptors
- Laboratory and Field Studies, Site Case Histories
- In Situ and Ex Situ Bioremediation
- Modeling
- Regulatory, Economic, and Public Perception Issues

The keynote speaker for the symposium will be Dr. Barry Commoner, noted environmental scientist and author. Battelle will be mailing a preliminary program in early November 1992. Proceedings will be published by Lewis Publishers.

Limited space is still available for additional posters. If you are interested in presenting a poster, please submit a one-page abstract to Rob Hinchee, Bioremediation Symposium Chair, Battelle, 505 King Avenue, Columbus, OH 43201-2693, USA, fax: 614-424-3667. For information on registering or exhibiting, contact Phillip Wells of the Conference Group at 800-783-6338 (fax: 614-488-5747).

Addressing Land Disposal Restrictions in Biotreatment

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meaning the waste must be treated until a certain concentration of hazardous constituents is attained. Other wastes have technology-based standards for situations in which there is no analytical method. Therefore, the waste must be treated by certain methods, deemed Best Demonstrated Available Technologies (BDATs). If biotreatment cannot perform adequately for a waste with a concentration-based standard, a variance must be obtained or an alternative technology substituted.

Contaminated Debris

The LDR Contaminated Debris Rule defines hazardous debris as any solid material intended for discard that is contaminated with hazardous waste or that exhibits one or more of the hazardous waste characteristics. To be classified as debris, the solid material must have a particle size in excess of 60 mm (2.5 in.) and be a manufactured object, plant or animal matter, or natural geologic material.

In the past, contaminated debris was subject to the concentration-based treatment standard for the particular waste with which the debris was contaminated. Adhering to this standard is still acceptable, but the new rule adds the option to treat hazardous debris with one or more BDATs specified for each debris/contaminant combination. These technologies are divided into extraction, immobilization, and destruction technologies. Biodegradation is identified as a destruction technology for several types of hazardous debris, including debris contaminated with most common organic compounds.

Contaminated Soil

Phase 2 of the rule, LDRs for Newly Listed Waste and Contaminated Soil, is scheduled for proposal in Fall of 1992 and promulgation in Spring of 1993. These will be published in the *Federal Register*. Bioremediation is a possible BDAT standard for contaminated soil, so EPA encourages biotreaters in the field to evaluate the proposed rule and comment accordingly. Until new treatment standards for contaminated soils are promulgated, however, biotreaters must comply with current LDRs, obtain a treatability variance, or apply for a no-migration petition from LDR standards.

Compliance Alternatives

Alternatives to compliance with the LDRs are available to biotreaters:

- *Treatability variances* to concentration-based treatment standards are available in the event that a particular waste is more difficult to treat than the waste on which the standard was based. There are two kinds of treatability variances: (1) variances with generic applicability, which apply to a specific waste at any site, and (2) site-specific variances, which apply only to a particular waste at a specific site. For more information on site-specific variances, refer to *Regional Guide: Issuing Site-Specific Treatability Variances for Contaminated Soils and Debris from Land Disposal Restrictions (LDRs)* (Office of Solid Waste and Emergency Response [OSWER] Directive 9380.3-08FS), which can be ordered by calling the RCRA/Superfund Hotline at 800-424-9346 or 703-920-9810 in the Washington, DC area.

- *No-migration petitions* are granted if an applicant can demonstrate that hazardous waste will not migrate from the place of disposal for as long as the waste remains hazardous. These petitions may be especially useful for biotreaters considering land treatment, in which soil is treated and left in place. For more information on no-migration petitions for RCRA sites, see *Variances to the Hazardous Waste Land Disposal Prohibitions: A Guidance for Petitioners*. For more information on no-migration petitions for Superfund sites, refer to OSWER Directive 9347.3-10FS, which also can be ordered by calling the RCRA/Superfund Hotline.

- The concept of the *corrective action management unit (CAMU)* was established by the proposed Subpart S under RCRA for corrective action. This concept allows RCRA sites to treat wastes and contaminated soils within the CAMU without triggering the LDRs. The CAMU portion of Subpart S is scheduled for promulgation in December 1992. For more information on CAMU exemptions, refer to the *Federal Register* (55 FR 30789).

- An *LDR BDAT exemption for ground-water reinjection* is available. This exemption will be useful for RCRA and CERCLA bioremediation sites where ground water is pumped to the surface to be amended, then reinjected. For more information on reinjection exemptions, refer to OSWER Directive 9234.1-06.

For more information, contact Michael Forlini of OSWER's Technology Innovation Office at 703-308-8825, or call the RCRA/Superfund Hotline at 800-424-9346 or 703-920-9810 in the Washington, DC area.

FIELD APPLICATIONS OF BIOREMEDIATION[1]

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
I	Baird and McGuire Holbrook, MA CERCLA Fund Lead	David Lederer (617)573-5738 Evelyn Tapani (617)556-1125	Ground water: petroleum, wood preserving, pesticides (chlordane).	Being installed: full scale. Incurred cost: $11M Expected cost: $11M.	Ground water: MCLs.	Ex situ treatment, activated sludge, continuous flow. Aerobic conditions, exogenous organisms. Other technologies: chemical extraction. 100% of site under bioremediation.	None.
I	Charles George Landfill Tyngsboro, MA CERCLA Fund Lead	David Dickerson (617)573-5735 Dale Young (617)292-5785	Ground water: benzene, wood preserving (arsenic).	Predesign. Remediation expected start: 11/94. Remediation expected completion: 01/2020.	Ground water: arsenic, 30 µg/L; benzene, 5 µg/L.	Ex situ treatment, activated sludge, continuous flow. Aerobic conditions, exogenous organisms. Other technologies: activated sludge for leachate, preaeration, carbon filtering.	None.
I	Charlestown Navy Yard Boston, MA CERCLA State Lead	Stephen Carlson (617)242-5680	Sediments: wood preserving (PAHs).	Design: pilot scale.	Not yet established.	In situ treatment. 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.	Predesign. Remediation expected start: 01/94. Remediation expected completion: 01/2005.	Ground water: NPDES requirements.	Other technologies: metal precipitation and air stripping. 50% of site under bioremediation.	None.
I	General Electric Pittsfield, MA TSCA Lead (Federal)	Joan Blake (202)260-6236	Sediments: PCBs. Volume: 12 cubic meters.	Design: pilot scale.	Sediments: PCBs, 2 ppm.	In situ treatment. 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.	Design: pilot scale.	Sediments: PCBs, 2 ppm.	In situ treatment, confined treatment facility, nutrient addition. Anaerobic conditions, indigenous organisms. Other technologies: incinerator, flotation separation.	None.
I	Iron Horse Park Billerica, MA CERCLA Enforcement Lead	Don McElroy (617)223-5571	Sludge / soil (vadose: sand, loam): PAHs, petroleum. Volume: 20K cubic yards.	Operational: full scale. Remediation start: 11/91. Remediation expected completion: 01/96. 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/RECRA/UST sites considering, planning, operating or which have used bioremediation.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
I	Sylvester** Nashua, NH CERCLA State Lead	Chet Janowski (617)573-9623 Paul Hientzler (603)882-3631	Ground water: solvents (vinyl chloride, benzene, chloroform, MEK, PCE, phenols, selenium, TCE, 1,1,2-trichloroethane, chlorobenzene, methylene chloride, toluene, 1,1-dichloroethane, trans-1,2-dichloroethane, 1,1,1-trichloroethane, methyl methacrylate).	Operational: full scale. Remediation start: 06/86. Remediation expected completion: 07/94. Incurred cost: $15M Expected cost: $20M.	Ground water: vinyl chloride, 95 ppb; benzene, 340 ppb; chloroform, 1,505 ppb; MEK, 8,000 ppb; PCE, 57 ppb; phenols, 400 ppb; selenium, 2,600 ppt; 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 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 (vadose and saturated): PAHs, VOCs, petroleum (lube oil). Volume: 4,375 cubic yards.	Operational: full scale. Remediation start: 07/91. Remediation expected completion: 10/92.	Soil (vadose and saturated): TCLP to meet soil guidance levels.	Ex situ land treatment. Aerobic conditions, indigenous organisms. 100% of site under bioremediation.	Contaminated soil is applied in 2-foot layer; nutrients are added and soil is tilled by mechanical means. Bioremediation of first lift is complete; preparation is beginning for second lift.
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.	Design. Expected cost: capital, $286K; O&M, $200K.	Soil (saturated): New Jersey Soil Action Level. Ground water: New Jersey MCLs.	In situ treatment, nutrient addition (soil), nutrient addition and 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.	Predesign: laboratory scale. Incurred cost: $2.6M.	Not established.	In situ treatment. Aerobic conditions, indigenous organisms. 1% of site underwent bioremediation.	Bioremediation is inefficient for PCBs.
II	General Motors—Central Foundry Division Massena, NY CERCLA Enforcement Lead	Lisa Carson (212)264-6857	Sediments / sludge / soil (vadose and saturated): HAHs (PCBs). Volume: 350K cubic yards.	Treatability studies conducted or in progress. Remediation expected start: 04/93.	Sludge: PCBs, 10 ppm (risk-based). Sediments: PCBs, 1 ppm (risk-based). Soil (vadose and saturated): PCBs, 10 mg/kg (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.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
II	Knispel Construction Site Horsehead, NJ UST Lead (State)	Frank Peduto (518)371-9153	Soil (vadose and saturated) / ground water: petroleum.	Completed: full scale. Remediation start: 01/89. Remediation completion: 10/89. Incurred cost: O&M, $250K.	Ground water: petroleum, 5 ppb (drinking water standards). Soil (vadose and saturated): petroleum, 5 µg/kg (drinking water standards).	In situ land treatment, hydrogen peroxide, nutrient addition (water). Aerobic conditions, indigenous organisms. 100% of site underwent bioremediation.	None.
II	Mobil Terminal Buffalo, NY CERCLA Enforcement Lead	Robert Leary (716)851-7220 Mike Hinton (716)851-7220	Soil (vadose and saturated): petroleum (gas and diesel), lead. Volume: 10K cubic yards.	Operational: full scale. Remediation start: 07/91.	Soil (vadose and saturated): 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	Famaz Saghafi (212)264-4665 Anton Mawarajah (609)633-6798 Pat Evangelista (212)264-6311	Ground water: methylmethacrylate, lead.	Predesign: laboratory scale. Remediation expected start: 09/93. Remediation expected completion: 01/96.	Ground water: methylmethacrylate, 350 ppb (NJ Interim Soil Action Levels).	Ex situ treatment, contact stabilization, continuous flow. Aerobic conditions, indigenous organisms. Other technologies: solidification and stabilization of site soils contaminated with lead.	None.
II	Osmose Buffalo, NY CERCLA State Lead	Jim Harrington (518)485-8792 Jaspal Walia (716)851-7220	Soil (vadose and saturated): wood preserving, petroleum (fuel oil). Volume: 670 cubic yards.	Operational: full scale. Remediation start: 09/90. Expected cost: $125K.	Not yet established.	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.	Design: pilot scale. Remediation 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 (vadose and saturated): petroleum. Volume: 6,000 cubic yards.	Completed: full scale. Remediation start: 07/90. Remediation completion: 11/91.	Soil (vadose and saturated): 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.
III	ARC Gainesville, VA RCRA Lead (Federal)	Robert Stroud (215)597-6688 Patrick Grover (804)225-2863	Soil (vadose and saturated): solvents (chlorobenzene). Volume: 2,000 cubic yards.	Completed: full scale. Remediation start: 10/89. Remediation completion: 06/91.	Soil (vadose and saturated): chlorobenzene, 0.014 mg/kg (technology effectiveness).	In situ treatment, bioventing. Aerobic conditions, exogenous organisms. Other technologies: pump and treat, soil shredding proposed. 5% of site underwent bioremediation.	Facility was required to submit a closure plan to the state of VA; however, this requirement no longer exists.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
III	Atlantic Wood Portsmouth, VA CERCLA Enforcement Lead	Ronald Davis (215)597-1727 Steve Mihalko (804)255-3263	Sediments / soil (vadose and saturated): wood preserving (PCP, PAHs), dioxins, furans.	Treatability studies conducted or in progress.	Not yet established.	Ex situ land treatment. Other technologies: soil washing, thermal desorption, incineration.	Type of treatment won't be determined until review of feasibility study results. The presence of metals and dioxins and furans might be a problem.
III	Avtex Fibers Front Royal, VA CERCLA Enforcement Lead	Bonnie Gross (215)597-9023	Ground water: arsenic, zinc, lead, carbon disulfide, cadmium, hydrasulfide.	Design. 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.	None.
III	Dover Air Force Base* Dover, DE Federal Facility Process 1 Process 2 Process 3 Process 4	Milton Beck (302)677-6845 Rob Allen (302)323-4540	Soil (vadose sand) / ground water: petroleum, metals (lead). Volume: 15K cubic yards. Soil (vadose and saturated sand) / ground water: solvents, iron, manganese. Volume: 50K cubic yards. Soil (vadose silt): petroleum, PAHs, TCE. Soil (vadose: sand, silt): petroleum. Volume: 300K cubic yards.	Treatability studies conducted or in progress: full scale. Remediation expected start: 11/92. Treatability studies conducted or in progress: full scale. Remediation expected start: 01/93. Predesign: full scale. Remediation expected start: 08/93. Predesign: full scale. Remediation expected start: 09/93. Incurred cost: O&M, $100K Expected cost: $1.2M.	Soil (vadose): petroleum, 10 mg/kg; petroleum, 1,000 mg/kg; lead, 500 µg/kg (risk-based). Ground water: risk-based. Not yet established. Soil (vadose): petroleum, 10 mg/kg; petroleum, 1,000 mg/kg (risk-based). Soil (vadose): petroleum, 1,000 mg/kg; petroleum, 10 mg/kg (risk-based)	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. Other technologies: vacuum extraction. In situ treatment, air sparging. Aerobic conditions, indigenous organisms. Other technologies: vacuum extraction. In situ treatment, bioventing. Aerobic conditions, indigenous organisms. In situ treatment, air sparging, bioventing. Ex situ land treatment. Aerobic conditions, indigenous organisms. Other technologies: vacuum extraction, asphalt binding.	Problem with free product and ground-water contamination. Site has solvents in ground water, high iron and manganese. None. Site has free product soil contamination under aircraft parking apron.
III	Drake Chemical Lock Haven, PA CERCLA Fund Lead	Roy Schrock (215)597-0517	Soil (vadose and saturated) / ground water: pesticides, solvents (DCE), herbicides (fenac).	Predesign.	Not yet established.	Aerobic attached growth.	None.
III	L.A. Clarke & Son VA CERCLA Enforcement Lead	Gene Wingert (215)597-1727	Sediments / soil (vadose and saturated): wood preserving. Volume: 119K cubic yards.	Design: pilot scale. Expected cost: $23M.	Not yet established.	In situ treatment, creosote recovery. Other technologies: soil flushing. 25% of site under bioremediation.	None.
III	Ordnance Works Disposal Area Morgantown, WV CERCLA Enforcement Lead	Drew Lausch (215)597-1286 Riad Tamir (304)378-2745	Soil (vadose and saturated): PAHs, arsenic, cadmium, copper, lead. Volume: 42K cubic yards.	Predesign: laboratory scale. Expected cost: $8.3M.	Soil (vadose and saturated): carcinogenic PAHs, 44.7 mg/kg (risk-based).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Other technologies: solidification of inorganics.	Treatability studies planned. Unilateral administrative order issued June 1990.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
III	Whitmore Labs Myerstown, PA CERCLA Enforcement Lead	Christopher Corbett (215)597-6906 Noreen Chamberlain (717)657-6309	Soil (vadose and saturated): solvents (benzene, trichloroethane, tetrachloroethane, aniline), arsenic. Volume: 4,000 cubic yards.	Predesign. Remediation expected start: 06/93.	Soil (vadose): benzene, 0.009 mg/kg; trichloroethane, 0.017 mg/kg; tetrachloroethane, 0.051 mg/kg; aniline, 0.009 mg/kg. Soil (saturated): benzene, 0.002 mg/kg; trichloroethane, 0.004 mg/kg; tetrachloroethane, 0.012 mg/kg; aniline, 0.002 mg/kg.	Ex situ treatment. Other technologies: chemical treatment, fixation, incineration, containment, pump and treat. 10% of site under bioremediation.	None.
IV	Alabama State Docks Mobile, AL RCRA-Federal for soil; RCRA-State for ground water Process 1 Process 2	Nancy Bethune (404)347-3433 Clyde Sherer (205)271-7726	Ground water: arsenic, chromium, benzene, wood preserving (PCP), lead. Soil (vadose and saturated) / ground water: benzene, chromium, arsenic, wood preserving (PCP).	Operational: full scale. Remediation start: 09/91. Remediation expected completion: 02/93. Completed: full scale. Remediation start: 09/91. Remediation completion: 01/92.	Ground water: arsenic, 0.05 mg/L; chromium, 0.05 mg/L; benzene, 0.005 mg/L. Not established.	Aerobic attached growth. In situ land treatment. Ex situ treatment, slurry reactor.	None. None.
IV	American Creosote Works—O.U. #1 Jackson, TN CERCLA Fund Lead	Tony DeAngelo (404)347-7791 Ron Sells (901)423-6600 Betty Maness (901)423-6600	Soil (vadose and saturated: sand, silt) / ground water: wood preserving (PCP), PAHs, chromium (+3), copper, silver.	Predesign.	Ground water: carcinogenic PAHs, 100 ppm. Soil (vadose and saturated): carcinogenic PAHs, 100 mg/kg.	Other technologies: partial removal of sludges (creosote) and highly contaminated soils for offsite incineration.	State may not have 10% cost-share for any remedial action to be undertaken.
IV	American Creosote Works—O.U. #2 Jackson, TN CERCLA Fund Lead	Tony DeAngelo (404)347-7791 Ron Sells (901)442-6600	Ground water: wood preserving (PCP).	Predesign. Remediation expected start: 12/95. Remediation expected completion: 12/98.	Ground water: wood preserving, 100 ppm.	Not yet established.	Hydrogeologic investigation underway. Remedial action contingent upon receiving 10% cost share from state. Funds available for treatability studies only.
IV	American Creosote Works—O.U. #3 Jackson, TN CERCLA Fund Lead	Tony DeAngelo (404)347-7791 Ron Sells (901)423-6600	Sludge / soil (vadose and saturated): wood preserving (PAHs, phenols). Volume: 100K cubic yards.	Predesign: pilot scale. Remediation expected start: 12/95. Remediation expected completion: 12/98.	Sludge: wood preserving, 100 ppm. Soil (vadose and saturated): wood preserving, 100 mg/kg.	Ex situ treatment, aerated lagoon. Aerobic conditions, indigenous organisms. Other technologies: incineration and carbon filtration. 50% of site under bioremediation.	Initiation of Operable Unit #3 awaiting close-out of Operable Unit #1. All remedial work contingent upon getting 10% cost share from state. State cost share not presently able to be contracted for. Can only get money for treatability studies and remedial investigations.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
IV	American Creosote Works—Pensacola Pensacola, FL CERCLA Fund Lead	Madolyn Streng (404)347-2643 Charles Logan (904)488-0190 Beverly Houston (404)347-3866	Soil (vadose and saturated): dioxin, wood preserving (PCP, PAHs). Volume: 30K cubic yards.	Design: pilot scale. Remediation expected start: 10/92. Remediation expected completion: 09/94. Expected cost: $5M.	Soil (vadose and saturated): 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. 75% of site under bioremediation.	Bioremediation not effective for remediation of dioxins in soils.
IV	Brookhaven Wood Preserving Brookhaven, MS CERCLA Fund Lead	De'Lyntoneus Moore (404)347-3931	Soil (vadose and saturated loam): wood preserving (PCP). Volume: 200 cubic yards.	Predesign: pilot scale. Remediation expected start: 05/93. Remediation expected completion: 05/94.	Soil (vadose and saturated): risk-based.	Ex situ land treatment. Aerobic conditions, exogenous and indigenous organisms. 1% of site under 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	Brown Wood Preserving Live Oaks, FL CERCLA Enforcement Lead	Martha Berry (404)347-2643 Charles Logan (904)488-0190	Soil (vadose and saturated): wood preserving (PCP, PAHs). Volume: 9,000 cubic yards.	Completed: full scale. Remediation start: 10/88. Remediation completion: 12/91.	Soil (vadose and saturated): 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 (vadose and saturated): wood preserving (PAHs, phenol, naphthalene, fluorine, PCP, arsenic, chromium). Volume: 6,700 cubic yards.	Completed: full scale. Remediation completion: 04/89.	Soil (vadose and saturated): 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 (vadose and saturated) / ground water and surface water: wood preserving (arsenic, PAHs, chromium). Volume: 4,000 cubic yards.	Predesign: laboratory scale.	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. Soil (vadose and saturated): PAHs, 1 mg/kg; carcinogenic PAHs, 2.5 mg/kg; arsenic, 94 mg/kg; chromium, 88 mg/kg.	Ex situ treatment, slurry reactor, batch flow. Other technologies: soil washing, solidification.	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.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
IV	Carolawn** Carolawn, SC CERCLA Enforcement Lead	Al Cherry (404)347-7791	Ground water: lead, solvents (acetone, cis-DCE, trans-DCE, TCA, TCE).	Design: pilot scale.	Ground water: acetone, 710 µg/L; cis-DCE, 70 µg/L; trans-DCE, 120 µg/L; TCA, 200 µg/L; TCE, 5 µg/L; lead, 5 µg/L.	Not yet established.	Partial consent decree issued 12/4/91. Work began 12/16/91: sampled inactive incinerators and drums of material. Undergoing UV oxidation treatability studies to determine potential for treatment of ground water. Site is mobilized; electrical power is on. Application has been submitted for a permit to construct observation wells.
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).	Operational: full scale. Remediation start: 10/88. Remediation expected completion: 09/99. 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, neutralization, filtration, air stripping, carbon adsorption. 100% of site under bioremediation.	Biomass upsets decreasing operating efficiency of treatment system. Cause of upset is unknown to date. COD removal efficiency for seventh operational quarter was 92% for wells located close to source. TOC was 87% removal efficiency.
IV	Coleman-Evans White House, FL CERCLA Fund Lead	Tony Best (404)347-2643	Soil (vadose and saturated): wood preserving (PCP), petroleum, arsenic. Volume: 27K cubic yards.	Design: pilot scale. Remediation expected start: 06/93. Remediation expected completion: 06/94. Expected cost: $8.6M.	Soil (vadose and saturated): PCP, 25 mg/kg.	Ex situ treatment, slurry reactor, batch flow. Aerobic conditions, exogenous organisms. Other technologies: soil washing, solidification/stabilization. Landfill: 100% under bioremediation. Operations: 50% under bioremediation.	Wood chip removal from soils; dioxins have been identified and are being evaluated. Bioremediation was found to be ineffective for dioxins.
IV	Dubose Oil Cantonment, FL CERCLA Fund Lead	Mike McKibben (404)347-2643	Soil (vadose and saturated: sand, clay): TPNA, PCP, petroleum, solvents (TCE, PCE). Volume: 15K cubic yards.	Design: laboratory scale. Remediation expected start: 12/92. Remediation expected completion: 03/95. Expected cost: $3M.	Soil (vadose and saturated): TPNA, 50 mg/kg; PCP, 50 mg/kg; xylene, 65 mg/kg; benzene, 10; TCE, 0.05 mg/kg; PCE, 0.07 mg/kg.	Ex situ land treatment. Other technologies: carbon adsorption. 90% of site under bioremediation.	Pilot study was delayed due to waiting for results of dioxins test.
IV	Koppers/Florence Florence, SC RCRA Lead (Federal)	Mike Arnett (404)347-7603	Soil (vadose and saturated): wood preserving (PCP, PAHs).	Predesign.	Not yet established.	Ex situ land treatment. Exogenous and indigenous organisms. Other technologies: ground-water extraction, pretreatment, discharge to POTW. 33% of site under bioremediation.	None.
IV	Langdale Facility** Sweetwater, TX RCRA Lead (Federal)	Charles Burroughs (615)741-3424	Sludge / soil (vadose and saturated): wood preserving.	Completed: full scale. Remediation completion: 01/89.	Not available.	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	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
IV	Shavers Farm Shelby County, GA CERCLA Fund Lead	Chuck Eger (404)347-3931	Soil (vadose and saturated): pesticides (dicamba), benzoic acid, dichlorosalicyclic acid, benzonitrite.	Treatability studies completed: pilot scale.	Soil (vadose and saturated): dicamba, 25 mg/kg; benzoic acid, 25 mg/kg; dichlorosalicyclic acid, 25 mg/kg; benzonitrite, 25 mg/kg.	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	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.	Treatability studies conducted or in progress: pilot scale. Remediation expected start: 01/93.	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 under bioremediation.	None.
IV	Southeastern Wood Preserving MS CERCLA Fund Lead	Don Rigger (404)347-3931	Soil (vadose and saturated): wood preserving. Volume: 10K cubic yards.	Operational: full scale. Remediation start: 04/90. Remediation expected completion: 04/93. Expected cost: $1.7M.	Soil (vadose and saturated): 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)	Pat Anderson (404)347-3433 Stan Sullivan (205)271-7730	Soil (vadose and saturated) / ground water: wood preserving (PCP).	Predesign: full scale.	Not yet established.	Ex situ treatment, sequencing batch reactor, slurry reactor, batch flow. 100% of site under bioremediation.	None.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	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 (vadose and saturated) / ground water: petroleum, solvents (benzo(a)pyrene, chlorobenzene, 1,4-dichlorobenzene, di-n-butyl phthalate, methylene chloride, 2-methyl napthalene, napthalene, phenol, tetrachloroethene, trichloroethene, acetone, bis-phthalate, carbon disulfide, ethylbenzene, methylethyl ketone, 3,4-methylphenol, 2-methylnapthalene), PCB 1260, lead. Volume: 40.7K cubic yards.	Predesign. Remediation expected start: 06/93. Remediation expected completion: 06/94. Expected cost: capital, $15.5M; O&M, $3.4M.	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-phthalate, 0.004 mg/L (ARAR-based); carbon disulfide, 1.64 mg/L (risk-based); ethylbenzene, 0.7 mg/L (ARAR-based); methylethyl ketone, 8.46 mg/L (risk-based); 3,4-methylphenol, 0.85 mg/L (risk-based); napthalene, 9,700 mg/L (risk-based); 2-methylnapthalene, 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). Soil (vadose and saturated): benzene, 1.13 µg/kg (risk-based); benzo(a)pyrene, 0.192 mg/kg (risk-based); chlorobenzene, 970 mg/kg (ARAR-based); 1,4-dichlorobenzene, 0.012 mg/kg (risk-based); methylene chloride, 29.3 mg/kg (risk-based); PCB 1260, 0.09 mg/kg (risk-based); 2-methyl napthalene, 2.2 mg/kg (risk-based); napthalene, 0.261 mg/kg (risk-based); phenol, 0.549 mg/kg (risk-based); tetrachloroethene, 4.3 mg/kg (risk-based); toluene, 1,440 mg/kg (risk-based); trichloroethene, 0.0447 mg/kg (risk-based).	Ex situ treatment, slurry reactor, batch flow. Aerobic conditions, exogenous organisms. Other technologies: soil washing, stabilization and solidification. 71% of site under bioremediation.	Solidification/stabilization will follow 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: PAHs. Volume: 500K cubic yards.	Predesign: pilot scale since 04/91. Expected cost: $26M.	Sediments: carcinogenic PAHs, 100 mg/kg (risk-based).	In situ treatment. Aerobic conditions, indigenous organisms. 50% of site under bioremediation.	Lab work underway to increase bioavailability of PAHs through use of surfactants, and to facilitate the delivery of oxygen to the waste matrix. Test plot is now operating according to design. Incurred cost for testing: over $2 million.
V	Allied Signal/Bendix St. Joseph, MI CERCLA Enforcement Lead	John Kuhns (312)353-6556 Sally Beebe (517)373-4110	Ground water: solvents (TCE, DCE, DCA, vinyl chloride).	Predesign: pilot scale. Remediation expected start: 12/93. Remediation expected completion: 12/98.	Not yet established.	In situ treatment. Aerobic and anaerobic conditions, indigenous organisms.	Recent sampling has identified much higher TCE concentrations, potentially toxic for aerobic organisms. Doing additional tests to examine two-phase anaerobic/aerobic system.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
V	Aristech Chemical Haverill, OH RCRA Lead (Federal)	Matthew Ohl (312)886-4442 Scott Schermerhorn (614)385-8501 Bob Volkmar (614)533-5412	Soil (vadose and saturated): cumene, phenol.	Operational: full scale. Remediation start: 07/91. Incurred cost: $180K Expected cost: $258K.	Soil (vadose and saturated): cumene, 4.67 mg/kg; phenol, 4.1 mg/kg (health risk-based).	In situ land treatment. Aerobic and anaerobic conditions, exogenous and indigenous organisms. 1% of site under bioremediation.	Aristech is still waiting for soil moisture to drop and soil temperature to rise before restarting.
V	Autostyle Kentwood, MI State Lead	Bonnie White (616)456-5071	Ground water: solvents (aromatic ketones), alcohol.	Operational: full scale. Remediation start: 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 (vadose and saturated) / ground water: petroleum (lube oil). Volume: 700 cubic yards.	Completed. Remediation start: 04/91. Remediation completion: 12/92. Incurred cost: $341K Expected cost: $20K.	Ground water: 100 x MN Department of Health RALs. Soil (vadose and saturated): BTEX, 50 mg/kg (risk-based).	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 has now converted to nonbiological process.
V	BP Oil Company Lima, OH RCRA Lead (Federal)	Jerry Grammas (419)226-2592 Gary Vanderembse (419)226-2744	Soil (vadose and saturated): petroleum.	Predesign: full scale.	Not yet established.	In situ land treatment.	Land treatment permit denied. Land treatment discontinued in September 1990. Working to achieve risk levels of 10^{-6} or 10^{-5} before closing, which will determine the land's final use. Full-scale study underway to determine whether bioremediation is appropriate at this site.
V	Burlington Northern Brainerd, MN CERCLA—State to start; RCRA—Federal since 1986	David Seep (612)490-6105 Frederick Jenness (612)297-8470 Richard Truax (303)493-3700	Soil (vadose sand) / ground water: wood preserving (PCP). Volume: 10K cubic yards.	Operational: full scale. Remediation start: 01/87. Remediation expected completion: 01/94. Incurred cost: capital, $725K; O&M, $38.6K. Expected cost: O&M, $38.6K.	Ground water: carcinogenic PCP, 28 mg/L; noncarcinogenic PCP, 300 mg/L.	In situ land treatment, nutrient addition (soil), pump and treat. Aerobic conditions, indigenous organisms. 100% of site under bioremediation.	Larger molecular weight compounds have degraded more slowly than expected.
V	Cliff/Dow Disposal Site Marquette, MN CERCLA Enforcement Lead	Ken Glatz (312)886-1434 Bruce Van Ottern (517)373-8427	Soil (vadose) / ground water: wood preserving (PAHs), arsenic, copper, lead, mercury. Volume: 9,000 cubic yards.	Predesign.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. 90% of site under bioremediation.	None.
V	Fisher-Calo LaPorte, IN CERCLA Fund Lead	Brad Bradley (312)886-4742	Soil (vadose and saturated) / ground water: PCBs, solvents (TCE, DCE, DCA).	Design: laboratory scale.	Ground water: TCE, 5 ppb; DCE, 70 ppb; DCA, 200 ppb (drinking water standards).	1% of site under bioremediation.	Only a remote possibility that bioremediation will be used to remediate entire site.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
V	Galesburg/Koppers IL CERCLA State Lead	Brad Bradley (312)886-4742 Steve Davis (217)785-3913	Soil (vadose and saturated): phenols, chlorophenol, PNAs, PCP, PAHs.	Predesign. Remediation expected start: 12/92.	Not yet established.	In situ treatment, nutrient addition. 100% of site under bioremediation.	None.
V	Hentchells Traverse City, MI UST Lead (State)	Ann Emington (616)775-9729	Soil (vadose and saturated) / ground water: petroleum.	Completed: full scale. Remediation start: 09/85. Remediation completion: 03/89.	Ground water: petroleum, 1,000 ppb.	In situ treatment. 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 (vadose and saturated): TNT, DNT, RDX.	Design: pilot scale.	Not yet established.	Ex situ treatment, slurry reactor, batch flow. Aerobic conditions, exogenous 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.	Operational: full scale. Remediation start: 08/89. Remediation expected completion: 09/94.	Soil (vadose): PCP, 150 mg/kg; PAHs, 100 mg/kg (dermal contact).	Ex situ land treatment. Aerobic conditions, indigenous organisms. 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* MI Federal Facility	Maeve Morgan (906)346-2342 Mark Petrie (906)228-6561	Soil (vadose sand): petroleum.	Treatability studies conducted or in progress: pilot scale.	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.	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	Marathon Station-Ervines Kentwood, MI State Lead	Bonnie White (616)456-5071	Ground water: petroleum (gasoline).	Operational: full scale. Remediation start: 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.	Operational: full scale. Remediation start: 05/90. Remediation 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, ambient air. Aerobic conditions, indigenous organisms. 100% of site under bioremediation.	None.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
V	McGillis Gibb MN CERCLA Fund Lead	Daryl Owens (312)886-7089 Douglas Robohm (612)296-7717	Ground water: wood preserving (PCP).	Predesign: full scale. Remediation expected start: 09/93. Remediation expected completion: 04/95. Expected cost: capital, $260K; O&M, $600K.	Ground water: POTW pretreatment standards.	Ex situ treatment, fixed film, plug flow. Aerobic conditions, indigenous organisms. Other technologies: soil washing and incineration under consideration. 10% of site under bioremediation.	A full-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.
V	Moss-American** Milwaukee, WI CERCLA Enforcement Lead	Betty Lavis (312)886-4784	Sediments / soil (vadose and saturated): wood preserving. Volume: 86.5K cubic yards.	Predesign. Remediation expected completion: 01/94.	Sediments: wood preserving, 6.1 mg/kg (risk-based). Soil (vadose and saturated): 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 under 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).	Operational: full scale. Remediation start: 11/91. Expected cost: $6M.	Ground water: ethylbenzene, 68 µg/L; methylene chloride, 473 µg/L; methyl phthalate, 9.2 µg/L.	Ex situ treatment, fixed film, rotating biological. 100% of site under bioremediation.	Calcium carbonate precipitation causing plugging. Fungi entering with effluent causing plugging.
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.	Design: laboratory scale. Remediation expected start: 05/93. Remediation expected completion: 09/96. Expected cost: capital, $400K; O&M, $20K.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. 20% of site under bioremediation.	In pre-final design stage. Construction expected May 1993. Soils outside of landfill to be addressed—methane in landfill.
V	Organic Chemical MI CERCLA Fund Lead	Tom Williams (312)886-6157	Ground water: TCE, toluene, petroleum (lube oil).	Predesign: laboratory scale.	Not yet established.	Other technologies: ground-water pump and treat as interim measure until levels of organics are reduced.	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 expected start: September 1992.
V	Parke-Davis Holland, MI RCRA Lead (Federal)	Shari Kolak (312)886-6151 Dave Slayton (517)373-8012	Soil (vadose and saturated) / ground water: petroleum, solvents.	Predesign.	Not yet established.	Not yet established.	None.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
V	Rasmussen Livingston County, MI CERCLA Enforcement Lead	Ken Glatz (312)886-1434 Denise Gruben (517)335-3386	Ground water: solvents (acetone, 2-butanone, 4-methyl-2-pentanone).	Predesign.	Ground water: acetone, 700 ppb; 2-butanone, 350 ppb; 4-methyl-2-pentanone, 350 ppb.	Ex situ treatment, fixed film. Exogenous organisms. Other technologies: chemical treatment, air stripping/carbon adsorption with nutrient addition. 100% of site under bioremediation.	None.
V	Reilly Tar IN CERCLA Enforcement Lead	Dion Novak (312)886-4737	Ground water: benzene, pyridine, ammonia. Volume: 13.6M cubic yards.	Predesign: laboratory scale. Expected cost: $15M.	Not yet established.	Ex situ treatment, sequencing batch reactor, continuous flow. Other technologies: chemical extraction. 100% of site under 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.
V	Reilly Tar & Chemical Company** St. Louis Park, MN CERCLA State 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). Volume: 1 cubic yard.	Predesign: laboratory scale. Incurred cost: $25K Expected cost: $70K.	Not yet established.	In situ treatment, bioventing, nutrient addition. Aerobic conditions, indigenous organisms. Other technologies: carbon adsorption. 1% of site under bioremediation.	Site will initiate a 3-year field evaluation of bioventing in November 1992.
V	Seymour Recycling IN CERCLA Enforcement Lead Process 1 Process 2	Jeff Gore (312)886-6552 Prebhakar Kasarabada (317)243-5130	Ground water: solvents (vinyl chloride, TCE, DCE, benzene, chloroethane). Volume: 500K gallons. Soil (vadose and saturated): solvents (vinyl chloride, TCE, DCE). Volume: 111K cubic yards.	Completed: full scale. Remediation completion: 09/90. Incurred cost: $1M. Completed: full scale. Remediation completion: 09/90. Incurred cost: $750K.	Ground water: drinking water standards. Not established.	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, IL CERCLA Enforcement Lead	Bonnie Eleder (312)886-4885 Ron Schmidt (608)267-7569	Sediments (sand, silt, clay): PCBs. Volume: 2,700 cubic yards.	Design: pilot scale.	Not yet established.	In situ treatment, no enhancement of process. Ex situ treatment, confined treatment facility (tank). Aerobic and anaerobic conditions, exogenous and indigenous organisms.	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.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
V	Sleeping Bear Dunes National Lakeshore** Empire, MI Federal Facility	John Wilson (405)332-8800 Guy Sewell (405)332-8800	Ground water: petroleum. Volume: 1,000 gallons.	Completed: full scale. Remediation start: 02/91. Remediation completion: 02/92.	Not established.	In situ treatment. Anaerobic conditions, indigenous organisms. 100% of site underwent bioremediation.	Site had an excess of isomers.
V	Spiegelberg Landfill Livingston Township, MI CERCLA Enforcement Lead	Ken Glatz (312)886-1434 Denise Gruben (517)335-3386	Ground water: solvents (2-butanone, hexanone).	Predesign.	Ground water: 2-butanone, 350 ppb; hexanone, 50 ppb.	Ex situ treatment. Exogenous organisms. Other technologies: air stripping/carbon adsorption with nutrient addition. 100% of site under bioremediation.	None.
V	St. Louis Interlake/Duluth Tar Site Duluth, MN CERCLA State Lead	Ann Bidwell (612)296-7827	Sediments / soil (vadose and saturated): VOCs, PAHs.	Predesign. Remediation expected start: 01/93.	Not yet established.	Not yet established.	Bioremediation for PAH-contaminated soils. Sediments had not been selected for treatment as of March 1992. The supplemental RI is not for the soils; operable unit is currently being completed.
V	Union Carbide OH CERCLA Enforcement Lead	Kathleen Warren (312)353-6756 Scott Bergreen (614)385-8501 Terry Roundtree (312)353-3236	Soil (vadose and saturated) / ground water: VOCs, dioxin, monochlorinated biphenyls, dichlorinated biphenyls, PCBs.	Treatability studies conducted or in progress: laboratory scale.	Not yet established.	In situ treatment of soil. Ex situ activated sludge treatment of ground water. Aerobic and anaerobic conditions, indigenous organisms. Other technologies: GAC.	None.
V	Upjohn Company Portage Facility Kalamazoo, MI RCRA Lead (Federal)	Lorna Jereza (312)353-5110 Greg Rudloff (312)335-3478	Soil (vadose and saturated) / ground water: solvents.	Predesign: pilot scale since 1987.	Not yet established.	Ground water: fixed film biomass with continuous flow reactor. 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-DCC, ethylbenzene, 1,1-dichloroethane).	Predesign. Design: expected 12/92. Remediation expected start: 01/93. Remediation expected completion: 01/94. 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-DCC, 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.	Problems include treatment of vinyl chloride and handling of water after treatment. There is no POTW (possible with installation of 3 miles of sewer line), no surface water discharge is possible, need to reinject.
VI	Atchinson Santa Fe, NM CERCLA Enforcement Lead	Susan Webster (214)655-6730	Sludge / soil (vadose and saturated): petroleum (diesel). Volume: 28K cubic yards.	Design: pilot scale. Expected cost: $3M.	Not yet established.	In situ land treatment. 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	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
VI	Dow Chemical Company* 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, 1,2-dichloroethylene, chloroethane). Volume: 90K cubic yards.	Being installed: full scale. Remediation expected start: 03/93. Incurred cost: capital, $250K; O&M, $10K. Expected cost: capital, $1M; O&M, $50K.	Not yet established.	In situ treatment, nutrient addition. Anaerobic conditions, indigenous organisms. Other technologies: pump and treat. 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	Sludge: arsenic, petroleum (BAP, PCB, VOCs).	Operational: full scale. Remediation start: 01/92. Remediation expected completion: 02/94. Expected cost: $90M.	Sludge: BAP, 9 ppm; PCB, 23 ppm; VOCs, 43 ppm; arsenic, 7 ppm; benzene, 14 ppm.	Ex situ treatment, aerated lagoon. Aerobic conditions, indigenous organisms. Other technologies: stabilization of residue. 100% of site under bioremediation.	None.
VI	Hudson Refining Company Cushing, OK RCRA Lead (Federal)	Brent Troskowski (214)655-6480	Soil (vadose): petroleum (lube oil), wood preserving (PAHs). Volume: 145K cubic yards.	Operational: full scale. Remediation start: 01/86.	Soil (vadose): 30% to 50% reduction of contaminants.	In situ land treatment, nutrient addition. 40% of site under bioremediation.	Lack of microorganisms; state order failed to specify cleanup levels; recontamination at nearby refinery.
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 (vadose and saturated: sand, silt, clay) / ground water: wood preserving (benzene, PAHs). Volume: 5,500 cubic yards.	Design: pilot scale. Remediation expected start: 10/93. Remediation expected completion: 09/96. Expected cost: $4M.	Soil (vadose and saturated): 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 carbon adsorption. 100% of site under 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 (vadose and saturated): petroleum. Volume: 200K cubic yards.	Being installed: full scale. Remediation start: 04/92. Remediation expected completion: 04/99. Incurred cost: $5.4M.	Sludge: contaminant reduction from 76% to 4%. Soil (vadose and saturated): contaminant reduction from 76% to 4%.	Ex situ treatment, continuous flow. Aerobic conditions, indigenous organisms. Other technologies: granular activated carbon. 70% of site under bioremediation.	None.
VI	Sheridan Disposal Services Houston, TX CERCLA Enforcement Lead	Ruth Izraeli (214)655-6735	Sludge / soil (vadose and saturated) / surface water: PCBs, solvents (benzene, toluene, ethylbenzene, phenol).	Predesign: pilot scale. Remediation expected start: 01/93. Remediation expected completion: 01/96. Expected cost: $28M.	Soil/sludge: PCBs, 25 ppm (PCBs as indicator of other organics).	Ex situ treatment, slurry reactor. Other technologies: stabilization of residues.	Pilot study completed; report due in April. Preliminary findings are hopeful.
VI	Texas Eastern Gas Pipeline Saint Francisville, LA TSCA Lead (Federal)	Joan Blake (202)260-6236	Soil (vadose and saturated): PCBs.	Treatability studies conducted or in progress: pilot scale. Remediation start: 05/91.	Not yet established.	Ex situ treatment.	Treatability study being carried out by a contractor hired by Texas Eastern.

* 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	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
VII	Amoco Refinery Sugar Creek, MO RCRA Lead (State)	Frank Dolan (314)751-3176 Alan Hancock (913)551-7647	Soil (vadose and saturated: silt, clay); petroleum (phenanthrene, pyrene, napthalene), lead. Volume: 137K cubic yards.	Operational: full scale. Remediation start: 09/90. Remediation expected completion: 01/99. Expected cost: capital, $10M; O&M, $13M.	Not yet established.	Ex situ treatment, sequencing batch reactor, 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 sludge mixing for uniformity and surface mixer on the Liquid Solids Reactor (aerated pond) 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: solvents (semivolatiles, VOCs), phenols. Volume: 2.4×10^9 gallons.	Operational: full scale. Remediation start: 04/90. Incurred cost: $110K Expected cost: 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).	Design: pilot scale. 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, nitrate. Aerobic conditions, indigenous organisms.	Possible future problems due to poor transmissivity of the aquifer.
VII	International Paper Joplin, MO RCRA Lead (State)	Frank Joplin (314)751-3176	Soil (vadose and saturated: silt, loam): wood preserving (PCP, PAHs). Volume: 70K cubic yards.	Operational: full scale. Remediation start: 06/92. Remediation expected completion: 01/2005. Expected cost: $9M.	Soil (vadose and saturated): 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. 100% of site under 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	Park City** Park City, KS CERCLA State Lead	John Wilson (405)332-8800	Ground water: petroleum (lube oil), benzene. Volume: 700K cubic feet.	Operational: full scale. Remediation start: 02/92. Remediation expected completion: 02/93. Incurred cost: $275K Expected cost: $650K.	Ground water: benzene, 5 µg/L (drinking water standards).	Ground water: in situ treatment. Possible bioventing for soils. Other technologies: soil washing, denitrification of BTEX.	Delays due to site serving as a test case for new Kansas environmental regulations.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
VII	Scott Lumber Alton, MO CERCLA Fund Lead	Bruce Morrison (913)236-3881	Soil (vadose): wood preserving (naphthalene, acenapthalene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)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).	Completed: full scale. Remediation start: 06/90. Remediation completion: 11/91. Incurred cost: 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-foot 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 (vadose and saturated: silt, loam, clay): PAHs (total), PAHs, petroleum (lube oil), cyanide. Volume: 100K cubic yards.	Design: pilot scale. Incurred cost: $250K Expected cost: $50-100 per cubic yard.	Soil (vadose and saturated): PAHs (total), 500 mg/kg; carcinogenic PAHs, 250 mg/kg.	Ex situ land treatment. Aerobic and anaerobic conditions, indigenous organisms. 90% of site underwent bioremediation.	High soil moisture, large area of operation, low temperatures, and other climatic obstacles.
VII	Vogel Paint & Wax Maurice, IA CERCLA State Lead	Steven Jones (913)551-7755 Bob Dnustrup (515)281-8900	Soil (vadose and saturated: silt, clay): petroleum (lube oil), solvents (MEK), lead, mercury. Volume: 10K cubic yards.	Operational: full scale. Remediation start: 07/91. Expected cost: $2M.	Not yet established.	Ex situ treatment, sludge added to heated waste, batch flow. Aerobic conditions, exogenous organisms. Other technologies: air stripping of ground water.	Volatilization control/air monitoring being evaluated.
VIII	Burlington Northern Glendive, MT Water Quality Bureau Lead	Terry Webster (406)444-2406	Soil (vadose and saturated): petroleum (diesel).	Operational: full scale. Remediation start: 01/91.	Soil (vadose and saturated): diesel, 100 mg/kg (EPA Recomended Washington Standard).	Ex situ land treatment. Aerobic conditions, indigenous organisms; active tillage, moisture and nutrient control; seasonal monitoring of contaminants. Monitoring below treatment zone once a year for leaching. 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 (vadose and saturated) / ground water: wood preserving (PAHs). Volume: 82K cubic yards.	Design: pilot scale. Operational: expected 01/93. Remediation expected completion: 01/2002. Expected cost: $11M.	Ground water: carcinogenic PAHs, 0.03 µg/L (water quality criteria). Soil (vadose and saturated): carcinogenic PAHs, 36 mg/kg (risk assessment).	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 under 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 (vadose and saturated): k048 organics, k051 organics, petroleum.	Operational: full scale. Remediation start: 01/73. Remediation expected completion: 01/2010.	Sludge: k048 organics, 1,000 ppm (closure performance standard).	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).

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
VIII	Exxon Landfarm Billings, MT RCRA Lead (State)	Mark Hall (406)444-4096	Sludge: k049 organics, k050 organics, k051 organics.	Operational: full scale. Remediation start: 01/80. Remediation expected completion: 01/2013.	Sludge: k049 organics, 1,000 ppm.	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, b-BHC, 4,4'-DDE, 4,4'-DDT, 4,4'-DDD), herbicides (2, 4-d).	Treatability studies conducted or in progress.	Not yet established.	In situ treatment. Ex situ treatment. Aerobic and anaerobic conditions, indigenous organisms.	None.
VIII	Hill Air Force Base UT Federal Facility	Robert Stites (303)294-1974	Soil (vadose and saturated): petroleum (JP4 jet fuel).	Operational: full scale. Remediation start: 09/91. Remediation expected completion: 09/93.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. Other technologies: vapor venting. 100% of site under bioremediation.	None.
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 (vadose and saturated) / ground water: pentachlorophenol, PAHs, dioxins/furans.	Predesign. Remediation expected start: 01/93.	Not yet established.	In situ land treatment, nutrient addition (water), nutrient addition (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).	Treatability studies conducted or in progress.	Not yet established.	In situ treatment. Ex situ treatment. Aerobic and anaerobic conditions, indigenous organisms.	None.
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, t-BHC lindane, b-BHC, 4,4'-DDE, 4,4'-DDT, 4,4'-DDD), herbicides (2, 4-d, dicamba, picloram (tordon), atrazine), triallates.	Treatability studies conducted or in progress.	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	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
VIII	Libby Ground-Water Site Libby, MT CERCLA Enforcement Lead	Julie Dalsoglio (406)449-5414 Jim Harris (406)449-5415	Soil (vadose and saturated) / ground water: wood preserving (PAHs, pyrene, PCP, dioxin, naphthalene, phenanthrene, benzene, arsenic). Volume: 45K cubic yards.	Operational: full scale. Remediation start: 05/91. Incurred cost: $4M.	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. Soil (vadose and saturated): 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.	In situ treatment of ground water. Ex situ land treatment. Also, treatment of ground water in bioreactor. 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. Only placed one lift.
VIII	Miles City Airport* Miles City, MT CERCLA State Lead	Carol Fox (406)449-4067	Soil (vadose and saturated): pesticides (aldrin, dieldrin, methyloxychlordane, chlordane, a-BHC, t-BHD lindane, b-BHC, 4,4'-DDE, 4,4'-DDT, 4,4'-DDD, ethyl parathion, endrin), herbicides (2, 4-d, picloram (tordon), atrazine), triallates (far-go).	Treatability studies conducted or in progress.	Not yet established.	In situ treatment. Ex situ treatment. Aerobic and anaerobic conditions, indigenous organisms.	None.
VIII	Montana Pole MT CERCLA State Lead	Brian Antonioli (406)449-4067 Sara Weinstock (406)449-5414	Sediments (silt) / soil (vadose and saturated silt) / ground water: PCP. Volume: 250K cubic yards.	Predesign: laboratory scale. Expected cost: capital, $10K; O&M, $300K.	Not yet established.	Other technologies: in situ soil flushing, soil washing.	The Montana Pole Site is in the RI/RS stage and no remediation is currently taking place. However, treatability studies have recently been conducted and reports are being revised at this time.
VIII	Montana Rail Link East Helena, MT Water Quality Bureau	Terry Webster (406)444-2406	Soil (vadose and saturated): petroleum (diesel).	Operational. Remediation start: 05/92.	Soil (vadose and saturated): diesel, 100 mg/kg (EPA Recomended).	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, MT Water Quality Bureau	Terry Webster (406)499-2406	Soil (vadose and saturated): petroleum.	Operational. Remediation start: 05/92.	Soil (vadose and saturated): petroleum, 100 mg/kg (EPA Recomended).	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.	Completed: full scale. Remediation start: 06/89. Remediation completion: 01/91. Incurred cost: $500K.	Ground water: risk-based.	In situ treatment, hydrogen peroxide, nutrient addition, combined bioprocess. 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.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
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, a-BHC, t-BHC lindane, b-BHC, 4,4'-DDE, 4,4'-DDT, 4,4'-DDD, methyl parathion, ethyl parathion), herbicides (2, 4-d, dicamba, atrazine), triallates (far-go).	Treatability studies conducted or in progress.	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 (vadose and saturated) / ground water: wood preserving (PAHs, PCP). Volume: 750K cubic yards.	Predesign: full scale. Remediation expected completion: 01/96. Incurred cost: $50M. 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; thus, bioremediation is not uniform.
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.	Operational: full scale. Remediation start: 07/92. Remediation expected completion: 07/95. Incurred cost: $30K. 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.	Design: pilot scale. Expected cost: 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.	Design: pilot scale. Expected cost: 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.	Design: full scale. Remediation expected start: 11/92. Remediation expected completion: 11/97. Expected cost: 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.	Design: pilot scale. Expected cost: 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.

* Indicates a new site.

FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
	Process 6		Soil (vadose silty clay): petroleum (diesel, gasoline), solvents (TCE), lead. Volume: 100K cubic yards.	Predesign: full scale. Remediation expected start: 06/93. Remediation expected completion: 06/96. Expected cost: 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.	Predesign: full scale. Remediation expected start: 10/93. Remediation expected completion: 10/95. Expected cost: capital, $30K; O&M, $6,000.	Soil (vadose): diesel, 50 mg/kg (state guidelines).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	Site recently discovered; little information available. Hope to install full-scale bioventing system.
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: 100M gallons.	Operational: full scale. Remediation start: 01/87.	Not yet established.	Ex situ treatment, fluidized bed. Aerobic conditions. Other technologies: chemical treatment, may also treat landfill liquids to see if ground water not heavily contaminated can be stripped; air stripping. 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 (vadose and saturated): petroleum. Volume: 70 cubic yards.	Completed: full scale. Remediation start: 11/88. Remediation completion: 01/89.	Soil (vadose and saturated): 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 (vadose and saturated silt): petroleum (diesel). Volume: 120 cubic yards.	Completed: full scale. Remediation start: 05/89. Remediation completion: 08/89.	Soil (vadose and saturated): diesel, 100 mg/kg.	Ex situ treatment, leachate recirculation, continuous flow. Aerobic conditions, indigenous organisms. Other technologies: leachate recirculation. 100% of site underwent bioremediation.	None.
IX	Converse/Montabello Corporation Yard Montabello, CA UST Lead (State)	Paul Hadley (916)324-3823	Soil (vadose): petroleum (gas, diesel).	Design: pilot scale.	Not yet established.	In situ treatment, bioventing, nutrient addition. Aerobic conditions, indigenous organisms. 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.	Design: pilot scale.	Not established.	Ex situ land treatment. Aerobic conditions, exogenous organisms. 100% of site underwent bioremediation.	None.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
IX	Former Service Station Los Angeles, CA UST Lead (State)	Tony Palagyi (818)505-2701	Soil (vadose and saturated) / ground water: petroleum. Volume: 3,000 cubic yards.	Completed. Remediation start: 11/88. Remediation completion: 03/91. Incurred cost: $1.6M.	Ground water: benzene, 5 ppb. Soil (vadose and saturated): TPH, 100 mg/kg.	In situ treatment, hydrogen peroxide, nutrient addition (water), closed loop system. 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 (vadose and saturated) / ground water: petroleum, solvents (MEK).	Design: pilot scale.	Ground water: MCLs.	In situ land treatment. Other technologies: pump and treat, carbon adsorption.	None.
IX	Gila Indian Reservation* AZ CERCLA Fund Lead	Richard Martin (415)744-2288	Soil (vadose and saturated): pesticides (toxaphene, parathion). Volume: 100K cubic yards.	Completed. Remediation start: 01/84. Remediation completion: 07/86. Incurred cost: $700K.	Soil (vadose and saturated): background.	In situ land treatment. Aerobic and anaerobic conditions, indigenous organisms. 100% of site underwent bioremediation.	Toxaphene is very hard to break down. Materials handling has been difficult.
IX	Growers Air Service** Woodland, CA CERCLA State Lead	Christine Holm (916)361-5703	Soil (vadose and saturated): pesticides (atrazine, BRAVO, chlorothalonil, dacthal, thiadine, 1&2-DDT, thiadine sulfate, trifluralin, methyl parathion, malathion, parathion, toxaphene, trithion, paroxon, methyl trithion, ethion).	Treatability studies conducted or in progress: laboratory scale.	Not yet established.	Ex situ land treatment.	The study was supposed to be on a pilot scale, but it ended up on a laboratory scale. The results were inconclusive due to many QA/QC problems in the analyses. The full-scale cleanup at this site has not begun. The Regional Board has not initiated action because of staff resource limitations. Future of bioremediation at site is unclear.
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, chlorfenyinphos, methidathion, monitor, nemacur, parathion-e, parathion-m).	Treatability studies conducted or in progress. Remediation expected start: 06/93. Remediation expected completion: 10/96.	Not yet established.	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, 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	Tony Luan (916)322-6872	Soil (vadose and saturated): pesticides. Volume: 65 gallons.	Design: pilot scale.	Not established.	Ex situ land treatment. Aerobic and anaerobic conditions, exogenous and indigenous organisms.	Pilot project completed. Evaluating field study results. Solid-phase bioremediation: pilot-scale tests on 13 5-gallon buckets of soil.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
IX	Hercules Incorporated Hercules, CA CERCLA State Lead	Tony Luan (916)322-6872	Soil (vadose and saturated): TNT, DNT, nitrobenzene. Volume: 1,500 cubic yards.	Design: pilot scale.	Soil (vadose and saturated): 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 Joan Fleck (707)576-2220 Ed Cargile (916)855-7858	Sediments (sand, silt) / soil (vadose and saturated: sand, silt): wood preserving (tetrachlorophenol, PCP, PAHs, dioxins, furans), arsenic, chromium, copper, zinc. Volume: 21.9K cubic yards.	Predesign. Design: expected 08/93. Remediation expected start: 01/94. Remediation expected completion: 01/2004. Expected cost: capital, $12.1M; O&M, $446K.	Sediments: tetrachlorophenol, 1 mg/kg (risk-based). Soil (vadose and saturated): PCP, 1.7 mg/kg; carcinogenic PAHs, 0.51 mg/kg; noncarcinogenic PAHs, 0.15 mg/L; dioxins, 0.001 mg/L; furans, 0.001 mg/kg (risk-based).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Other technologies: cement fixation for soils contaminated with inorganics.	Concern regarding effect of elevated metals on bioremediation process.
	Process 2		Ground water: wood preserving (PAHs, PCP, dioxins). Volume: 1.6×10^9 gallons.	Predesign: pilot scale. Design: expected 08/93. Remediation expected start: 10/93. Remediation expected completion: 01/2023. Expected cost: capital, $4.3M; O&M, $13.1M.	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.	Metals removal continues to be "spotty"— not a bioremediation issue.
IX	JASCO Mount View, CA CERCLA Fund Lead	Rose Marie Caraway (415)744-2235	Soil (vadose and saturated) / ground water: VOCs.	Treatability studies conducted or in progress: laboratory scale. Incurred cost: $30K.	Not yet established.	In situ treatment, composting being evaluated. 75% of site under bioremediation.	Treatability study being conducted while FS is on hold. Final FS will be produced following final treatability study.
IX	Koppers Company, Inc. Orville, CA CERCLA Enforcement Lead	Fred Schauffler (415)744-2365 Ed Cargile (916)855-7858	Soil (vadose: sand, clay, gravel, cobbles): wood preserving (PCP, PAHs, dioxins/furans). Volume: 110K cubic yards.	Predesign: full scale. Being installed: expected 04/93. Remediation expected start: 06/93. Remediation expected completion: 06/2013. Expected cost: 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, 0.0005 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 under bioremediation.	None.
IX	Liquid Gold Richmond, CA CERCLA Enforcement Lead	Rose Marie Caraway (415)744-2234	Soil (vadose and saturated): petroleum (waste oil), phenol, lead, zinc.	Predesign.	Not yet established.	Not yet established.	Metals contamination on site. Site is in preliminary stages of considering bioremediation technology; no decisions have been made and start of a treatability study is not planned.
IX	Marine Corps Air/Ground Combat Center Twenty-Nine Palms, CA CERCLA Fund Lead	Rosalind Dimenstein (619)346-7491	Soil (vadose and saturated): petroleum (jet fuel, gasoline, diesel, aviation fluid, transmission fluid).	Design: full scale.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	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	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): herbicides (silvex, 2,4,-d, 2,4,5-t). Volume: 550 cubic yards.	Operational: full scale. Remediation start: 10/91. Remediation expected completion: 10/92. Incurred cost: $30K Expected cost: $35K.	Soil (vadose): silvex, 50 mg/kg (state requirement).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Prepared bed with water and nutrients; periodic rototilling. Other technologies: photodegradation. 100% of site under bioremediation.	Laboratory support work has been poor.
IX	Montrose Chemical Corporation of California Torrance, CA CERCLA Enforcement Lead	Nancy Woo (415)744-2394 Alice Geniro (310)590-4931	Soil (vadose: silt, clay): pesticides (DDT), benzene, chlorobenzene, chloroform.	Predesign.	Not yet established.	Ex situ land treatment. Aerobic conditions, exogenous organisms.	RREL, Cincinnati has agreed to conduct tests at site. Region 9 is funding. If RREL does not pick up the project, it may get dropped because site is a PRP lead.
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).	Completed: full scale. Remediation start: 07/91. Remediation completion: 10/92. 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 on QA/QC of 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, napthalene, 1-methyl napthalene, n-butylbenzene), arsenic.	Design: pilot scale.	Not yet established.	In situ treatment, bioventing, nutrient addition (soil), oil/water separation. 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 (because of natural arsenic in ground water).
IX	Poly-Carb* NV CERCLA Fund Lead	Bob Mandel (415)744-2290	Soil (vadose and saturated): wood preserving (cresol, phenols). Volume: 1,500 cubic yards.	Completed. Remediation start: 06/87. Remediation completion: 09/88. Incurred cost: $450K.	Soil (vadose and saturated): 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 (vadose and saturated): petroleum. Volume: 700 cubic yards.	Completed. Remediation start: 08/88. Remediation completion: 12/89.	Soil (vadose and saturated): 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, seemed as effective in reducing the contaminant level as the site.

* Indicates a new site

FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
IX	Romic Chemical East Palo Alto, CA RCRA Lead (Federal)	Glenn Heyman (415)744-2044	Soil (vadose and saturated) / ground water: solvents (MEK, vinyl chloride, acetone, PCE, toluene, xylene, methylene chloride, DCE, MIBK).	Predesign.	Not yet established.	In situ treatment. Aerobic conditions, indigenous organisms. Other technologies: vacuum extraction, activated carbon, UV peroxidation. 100% of site under bioremediation.	High total dissolved solids in ground water; buildings on top of contaminated soil; facility borders on slough, which will recharge ground water during pump and treat.
IX	San Diego Gas and Electric San Diego, CA UST Lead (Federal)	Paul Hadley (916)324-3823	Soil (vadose and saturated): petroleum (gasoline). Volume: 1,200 cubic yards.	Operational: full scale. Remediation start: 10/89.	Not yet established.	In situ treatment. Anaerobic conditions, indigenous organisms. 100% of site under bioremediation.	None.
IX	Seaside High School Seaside, CA UST Lead (State)	Dick Ericksson (916)322-7046	Soil (vadose and saturated): petroleum (diesel). Volume: 100 cubic yards.	Completed: full scale. Remediation completion: 09/88.	Soil (vadose and saturated): 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 La Belle (916)324-2958	Soil (vadose and saturated): biphenyl, diphenyl ether.	Operational: full scale. Remediation start: 07/90.	Soil (vadose and saturated): biphenyl, 100 mg/kg; diphenyl ether, 1,000 mg/kg.	Ex situ treatment, pile.	None.
IX	Solvent Service CA CERCLA State Lead	Ron Gervason (415)464-0688 Marie Lacey (415)744-2234	Ground water: solvents (1,2 DCE, cis-1,2-DEC, trans-1,2 DCE, ethylbenzene, 111-TCA, freon 113, benzene, acetone, 1,1-DEC, napthalene).	Operational: full scale. Remediation start: 01/91. Remediation expected completion: 01/2001. Incurred cost: $399K Expected cost: $844K.	Ground water: 1,2 DCE, 5 µg/L; cis-1,2-DEC, 6 µg/L; trans-1,2 DCE, 10 µg/L; ethylbenzene, 400 µg/L; 111-TCA, 200 µg/L; freon 113, 1,200 µg/L; benzene, 0.7 µg/L; acetone, 400 µg/L; 1,1-DEC, 1 µg/L; napthalene, 2,000 µg/L.	Ex situ treatment, fixed film, continuous flow. Anaerobic conditions, exogenous organisms. Other technologies: vacuum extraction, steam enhancement of soil washing. 100% of site under bioremediation.	Have had difficulty obtaining a permit for bioremediation.
IX	Southern Pacific Transportation Company Roseville, CA CERCLA State Lead	David Wright (916)332-3910	Soil (vadose and saturated): petroleum.	Completed. Remediation start: 11/90. Remediation completion: 01/91. Incurred cost: $310K.	Soil (vadose and saturated): petroleum, 5,000 mg/kg.	Ex situ land treatment.	None.
X	American Crossarm Cahailis, WA CERCLA Fund Lead	Lee Marshall (206)553-2723 Mike Ruef (206)438-3059	Soil (vadose and saturated): wood preserving (PCP, PAHs, dioxins). Volume: 7 cubic yards.	Predesign.	Not yet established.	Not yet established.	None.
X	East 15th Street Service Station Anchorage, AK UST Lead (State)	Tony Palagyi (818)505-2701	Soil (vadose and saturated): petroleum (TPH diesel). Volume: 1,500 cubic yards.	Design. Remediation expected completion: 06/93. Incurred cost: $75K Expected cost: $200K.	Soil (vadose and saturated): TPH diesel, 100 mg/kg (regulatory guidelines).	In situ treatment, bioventing, land treatment. Aerobic conditions, indigenous organisms. Other technologies: vacuum extraction. 20% of site under bioremediation.	Winter weather has been an obstacle to bioremediation.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
X	Fairchild Air Force Base* Spokane, WA CERCLA Fund Lead 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).	Predesign. Remediation expected start: 01/95. Expected cost: 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).	Predesign: pilot scale. Remediation expected start: 04/93.	Soil (vadose): benzene, 0.5 mg/kg; petroleum, 200 mg/kg; TCE, 0.5 mg/kg.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	None.
	Process 3		Soil (vadose silt): petroleum.	Predesign: pilot scale. Remediation expected start: 04/93.	Soil (vadose): petroleum, 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	Soil (vadose and saturated complex mixture) / ground water: wood preserving (PAHs, PCP, TPH). Volume: 20K cubic yards.	Predesign. Design: expected 05/93. Being installed: expected 10/93. Operational: expected 02/94. Completed: expected 10/98.	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 (vadose and saturated): petroleum. Volume: 34K cubic yards.	Operational: full scale. Incurred cost: $3.5M.	Not yet established.	Ex situ land treatment. 40% of site under 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 accomodate alternative technologies.
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). Volume: 725 cubic yards.	Design: pilot scale.	Soil (vadose): PAHs, 50 µg/kg (permit standards).	In situ land treatment. Aerobic conditions, exogenous organisms. 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.

FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	COMMENTS
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).	Operational: full scale. Remediation start: 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. 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 wood treating site, additional aquifer and soil sampling will be conducted in November. Samples will be collected from an uncontaminated area, a contaminated area receiving nutrients and electron acceptor, and a contaminated area not receiving nutrients and electron acceptor. In addition to two fixed film reactors, two suspended growth reactors are also being operated in series.

At the Park City site, the permits are in place and funding for further remedial activity has been approved by the responsible party. The demonstration is starting this fall. Site characterization data have shown 130,000 gallons of refined product in 50,000 cubic yards of material and a total volume of 150,000 cubic yards containing contaminated ground water. The projected costs for treatment are $5 to $15 per cubic yard.

At the Allied Signal site, the second phase of the project is being undertaken to identify the nonaqueous phase liquid (NAPL) source areas for the ground-water plumes. Site characterization of the source areas is in progress.

The bioventing project at Eielson Air Force Base in Alaska has shown average soil temperatures this summer of 17°C in plots heated with warm water and enhanced solar warming using clear plastic mulching. Temperatures in the unheated plot and the uncontaminated background location were 13°C and 9°C, respectively. As expected, there was less temperature differential among the plots during this summer operation than during the winter operations.

At Hill Air Force Base in Utah, air injection rates were maintained at 65 cubic feet per minute in August and September, followed by the current rate of 35 cubic feet per minute. The first in situ respiration test was conducted in September and new soil-gas monitoring probes were installed at shallow depths.

The field demonstration at the Brookhaven wood preserving site was initiated in June. The white rot fungal species *Phanaerochaete sordida* was added to a 100 foot by 70 foot plot. Two control plots were also installed—one with contaminated soil only and the other with contaminated soil and the fungal spawn mix. Sampling will continue until November to monitor the disappearance of PCP and PAHs.

Further background information on these sites can be found in previous issues of the bulletin.

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