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Office of Solid Waste and Emergency Response
Office of Research and Development

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BIOREMEDIATION IN THE FIELD

An information update on applying bioremediation to site cleanup.

Update on the Bioremediation Field Initiative

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

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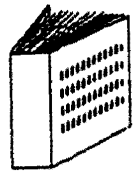

EPA Reviews New Rules for Microorganisms Under TSCA Section 5

EPA is in the process of reviewing draft proposed rules for microorganisms under the Toxic Substances Control Act (TSCA) section 5. TSCA authorizes EPA to regulate any chemical substance, except for certain substances covered by other federal agencies. Since the term chemical substance is defined broadly enough to cover microorganisms, the New Chemicals Program was the starting point for the development of biotechnology regulations under TSCA.

EPA currently operates the TSCA section 5 biotechnology program under a 1986 policy statement made as part of an interagency Coordinated Framework for Biotechnology (51 FR 23302, June 26, 1986). That policy statement will be in effect until EPA promulgates final rules to fully implement its biotechnology program. Draft rules entered the Agency's Red Border review process on December 27, 1991, and are expected to be sent to the Office of Management and Budget in 1992.

TSCA Uses

Similar to traditional chemicals, a microorganism is subject to premanufacture notification (PMN) reporting under TSCA section 5 when it is manufactured for a TSCA use and for commercial purposes. The definition of chemical substance in TSCA excludes pesticides, tobacco and tobacco products, food, food additives, drugs, cosmetics, and substances that are used as medical devices. Other than the exceptions described, all microorganisms produced for environmental, industrial, or consumer uses potentially may be regulated under TSCA. Potential TSCA uses of microorganisms include bioremediation of hazardous waste sites, enhanced oil recovery, metal extraction and concentration, and specialty chemical production.

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ERL, Gulf Breeze, and EPRI Study Bioremediation at Mercury-Contaminated Sites

The EPA Environmental Research Laboratory (ERL) in Gulf Breeze, Florida, and the Electric Power Research Institute (EPRI) are collaborating in research to evaluate the feasibility of using bioremediation to clean up a mercury-contaminated freshwater stream. East Fork Poplar Creek, the study stream in Oak Ridge, Tennessee, receives mercury from wastewater originating in the drainage system of a nearby nuclear plant.

The proposed strategy for remedial treatments is based on the stimulation of microbial reduction of Hg(II) and demethylation (both processes result in the partitioning of mercury to the atmosphere as Hg^0). This results in a decrease in CH_3Hg that is biologically available for accumulation in aquatic organisms, including fish. Stimulating the activity of indigenous microbes by adding limiting growth substrates and applying active exogenous bacteria is proposed as a remedial strategy.

The effectiveness of the remedial strategy will be established by manipulating calibrated microcosms containing intact samples from the field. Successful treatments then will be applied to enclosures placed in the pond for field testing. Microcosm validation (the process of verifying that the kinetics of mercury transformations in microcosms are similar to those in the field) will be achieved three ways:

- By following mercury biotransformations in field enclosures
- In microcosms containing intact field samples
- By using shake flask experiments with samples from the field site

Preliminary studies using shake flask experiments have demonstrated that several treatments stimulate microbial activities and chemical reactions which have resulted in the degradation of CH_3Hg and evolution of Hg^0. These treatments, which may form the basis for a bioremediation strategy, include:

- General stimulation of microbial activities by amendment with limiting nutrients. Concentrations of carbon, phosphorous, and nitrogen are limiting in the test stream.
- Application of naturally occurring nonengineered mercury-reducing microorganisms, and of Pseudomonad strains of bacteria that overexpress *mer* (mercury conversion) functions.

If the availability of substrates is found to limit mercury transformations, treatments aimed at controlling bioavailability, such as those affecting adsorption to particulates, will be designed and attempted.

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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.

RSKERL Increases Bioremediation Research and Technical Assistance at Superfund and RCRA Sites

The Robert S. Kerr Environmental Research Laboratory (RSKERL) continues to increase its activities in research, demonstration, and technical assistance with respect to the bioremediation of contaminants in the subsurface environment. These efforts are directed at the aqueous, solid, and vapor phases that comprise the subsurface matrix, and address water-soluble, immiscible, and residual phase contaminants.

While the RSKERL Technology Support Center (TSC) and its Core Team are the focus for technical assistance activities, they are supported by and closely associated with the Laboratory's in-house researchers and their extramural research counterparts, and the National Center for Ground-Water Research, a consortium of the University of Oklahoma, Oklahoma State University, and Rice University. An onsite contractor also provides direct support to TSC through its resident staff, treatability subcontractors, and over 100 consultants from the ground-water research and consulting community.

Technical Assistance Initiatives

Two major technical assistance initiatives are in place at the RSKERL Technology Support Center, including the Subsurface Remediation Information Center (SRIC) and the Center for Subsurface Modeling Support (CSMoS). SRIC provides a forum for the rapidly developing, highly specialized information in this scientific arena. Activities include collecting, evaluating, coordinating, and disseminating information relating to bioremediation as well as other protection and restoration processes associated with contaminants in soil and ground water.

CSMoS distributes and services all models and software developed at RSKERL, and provides assistance and training on modeling applications to ground water and the vadose zone. BIOPLUME II, for example, is a two-dimensional contaminant transport model applicable to biodegradation in ground water under the influence of an oxygen-limited environment. CSMoS is composed of RSKERL scientists and is supported by the International Ground-Water Modeling Center (IGWMC), the National Center for Ground-Water Research, and a number of ground-water modeling consultants. Training is available to regional and state personnel only; the models, however, are distributed to the public and private sector.

Treatability Studies

Another initiative of the RSKERL TSC is conducting treatability studies to provide specific information concerning the potential rate and extent of remediation of contaminants at specific hazardous waste sites. These studies are normally conducted in laboratory microcosms, at pilot scale facilities, or in the field, and are designed to determine whether a specific site is suitable for a particular technology, predominantly bioremediation. Subcontractors under the umbrella of the RSKERL TSC are available to conduct site-specific treatability studies of in situ technologies for EPA regional offices and for states, if requests are directed through regional offices. These studies are primarily for soil and ground-water bioremediation, as well as vacuum extraction and pump-and-treat technologies.

Technology Transfer

Technology transfer activities are an important part of the TSC bioremediation technical assistance agenda. Technology transfer may be carried out without specific requests or in response to generic needs suggested by EPA regional or headquarters offices. Technology transfer often takes the form of issue papers and briefing documents, workshops, and training courses for treating the subsurface. These activities are coordinated with the Center for Environmental Research Information.

Site-Specific Technical Assistance

Perhaps the most ambitious and complex undertaking of the RSKERL Technology Support Center is site-specific technical assistance. Since its beginning, TSC has been involved with over 250 site-specific requests for assistance, with 90 remaining active at this time. Predominantly, these requests are concerned with RI/FS documents, remedial design investigations, alternative technology evaluations, and treatability investigations. While some requests for assistance involve short-term reviews of technical documents, others result in extensive field and laboratory investigations using the laboratory's state-of-the-art equipment and technical innovations. Nearly half of the TSC technical assistance requests have centered on in situ soil and ground-water reclamation using bioremediation, land treatment, and modeling. The remaining activities have included pump-and-treat technologies, soil vacuum extraction, wellhead protection, and underground injection control. As with the treatability studies, assistance is available to the regions and also to the states, if the requests are directed through the regional office.

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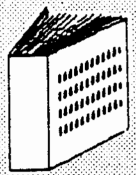

BAC Discusses Mission, Accomplishments, and Goals at February Meeting

EPA's Bioremediation Action Committee (BAC) met in Washington, DC, on February 12, 1992, to discuss its mission statement and goals, review the accomplishments of this past year, and plan the organization's direction for 1992 and beyond.

Mission Statement

Mr. Stephen Lingle, Deputy Director of ORD's Office of Environmental Engineering and Technology Demonstration (OEETD), began by presenting the BAC's draft mission statement, goals, and organizational structure. The draft mission statement identifies the BAC as an affiliation of industry, academia, and government representatives dedicated to advancing the responsible development and application of biotechnology to prevent, control, and remediate environmental contaminants. Routes for accomplishing this mission include identifying and addressing opportunities and barriers, documenting uses, and increasing public awareness.

The committee members then discussed the BAC's three broad goals:

1. The development of a national bioremediation response capability for oil spills.
2. The realization of bioremediation's full potential for treatment of hazardous waste.
3. The development of biotechnology's potential to prevent or reduce pollution.

Organization and Schedule

The BAC also reviewed and discussed its organizational structure and meeting schedule. To maintain flexibility in responding to changing needs and activities, the BAC has established a four-part structure that may be modified as necessary. The four parts are:

1. *Executive Committee.* Consisting of the BAC Chair, Executive Director, and Subcommittee chairs, this Executive Committee, or Board of Directors, defines direction, raises issues, makes decisions, and shares information.
2. *Steering Committee.* This core group of 25 to 50 individuals represents the clients served by the BAC. The Steering Committee acts as a sounding board and provides recommendations and guidance to the Executive Committee and subcommittees.
3. *Subcommittees.* The "working arms" of the BAC, each subcommittee has an area of focus defined by the subcommittee chair. Subcommittee findings are normally presented to the Executive Committee and approved by the BAC Committee Chair before general distribution.
4. *BAC Affiliates.* These include the individuals and organizations that are members of or participate in BAC committee or subcommittee activities.

The Executive Committee of the BAC will meet quarterly, with two of these meetings coinciding with the biannual meetings of the Steering Committee. One of the two Steering Committee meetings each year will include an expanded group of invitees and will report to the EPA Administrator and other EPA senior managers. Each subcommittee will meet on a schedule determined by its chair.

The BAC is an open organization, in which interested parties are welcome to participate. Anyone may attend Steering Committee meetings *subject to space availability*.

1991 Accomplishments and Future Plans

Each of the six BAC subcommittee chairs reported on accomplishments since the last BAC meeting in November 1990, and on plans for the next 18 months. Among the most significant accomplishments were the release of the following reports:

- *High Priority Research on Bioremediation.* A report on research needs as identified by a group of experts in bioremediation.
- *Interim Guidelines for Preparing Bioremediation Spill Response Plans.* A guide that is being used to finalize a spill response plan for the Texas coastline in EPA Region VI.
- *States Use of Bioremediation: Advantages, Constraints, and Strategies.* A report that discusses technological, economic, and political questions that states must answer before applying bioremediation in the field.

In the area of protocol development, the BAC highlighted two key accomplishments:

- The development of a draft of *Oil Spill Bioremediation Products Testing Protocol Methods Manual* by the National Environmental Technology Applications Corporation (NETAC).

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SITE Program Plans 15 Bioremediation Projects

Ten developers in the Superfund Innovative Technology Evaluation (SITE) Program have conducted or will conduct demonstrations with microbial treatment. A total of 15 projects are planned:

- Five involving in situ bioremediation
- Three using bioslurry reactors
- Three using fixed-carbon bioreactors for contaminated ground water
- One using powdered activated carbon mixed in activated sludge (the PACT process) for treating contaminated ground water
- Three using onsite surface soil microbial treatment technologies

Two of these projects have been completed to date and are described in detail below.

New Brighton, Minnesota–Fixed Film Bioreactor

The first of the two projects for which experimental work has been completed is a fixed-film bioreactor system operated by Biotrol, Inc. of Chaska, Minnesota. This system treated ground water contaminated with pentachlorophenol at a wood preserving facility in New Brighton, Minnesota, from July 24 to September 1, 1989. A 5 gpm, trailer-mounted unit was operated for 2 weeks at each of three throughput rates—1, 3, and 5 gpm—after an initial 2-week acclimation period.

The system uses PCP degraders in addition to indigenous organisms. Contaminated water enters a mixing tank where the pH is adjusted and inorganic nutrients are added. If necessary, the water is heated to reach the optimum temperature; a heat exchanger is used to minimize energy use. The water then flows to the reactor chambers where organic contaminants are biodegraded. The microorganisms are immobilized on a highly porous packing in a three cell, submerged fixed-film bioreactor. The biological growth is first developed during a short (1 or 2 week) acclimation period. Air is supplied by fine bubble membrane diffusers mounted at the base of each cell. The system, however, was designed so that it also could be operated under anaerobic conditions.

This technology is applicable to a wide variety of wastewaters, including ground water, holding ponds, and process effluents. Contaminants found to be amenable include pentachlorophenol, gasoline and fuel oil, chlorinated hydrocarbons, phenolics, and solvents. The resulting effluent may be discharged to a Publicly Owned Treatment Works (POTW), reused on site, or discharged directly under a National Pollutant Discharge Elimination System (NPDES) permit.

Table 1 summarizes the results of the 6-week study. The system successfully reduced the pentachlorophenol concentrations to less than 1 ppm in the effluent in one pass, producing minimal sludge and no air emissions of pentachlorophenol, and requiring minimal operator attention.

Table 1. Average Pentachlorophenol Removal

Flow (gpm)	Ground Water (PCP) (ppm)	Effluent (ppm)	Removal (%)
1	42.0	0.13	99.8
3	34.5	0.34	98.5
5	27.5	0.99	96.4

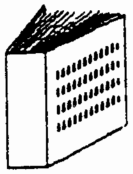
U.S. EPA Test and Evaluation Facility, Cincinnati, Ohio—Slurry Biodegradation

A pilot-scale slurry biodegradation project was conducted by Ecova Corporation of Redmond, Washington, at the U.S. EPA Test and Evaluation (T&E) facility located at the Gest Street Wastewater Treatment Plant in Cincinnati, Ohio. Six 60-liter EIMCO Biolift™ reactors were used to treat a creosote-contaminated soil from the Burlington Northern Superfund Site in Brainard, Minnesota. Stainless steel reactors are equipped with agitation, aeration, and temperature controls for the treatment of a slurry (20 to 30 percent by weight of the contaminated soil in water). Sampling ports are located along the side of each reactor at three vertical penetrations through the reactor wall.

Slurry biodegradation has been shown to be effective in treating highly contaminated soils and sludges that have contaminant concentrations ranging from 2,500 to 250,000 mg/kg. It has primarily been used to treat wood preserving wastes, coal tars, refinery wastes, and hydrocarbons.

During the 12 weeks of testing at the T&E facility, the total polynuclear aromatic hydrocarbons (PAHs) declined from an initial range of 119 to 14,681 mg/kg of soil to a range of 480 to 850 mg/kg of soil. This represented a reduction of 93.36 percent to 98.45 percent. The four-ring and larger polynuclear aromatic compounds only showed 80 to 90 percent removal, while the three-ring and smaller compounds showed removal between 93.3 and 98.4 percent. These results were consistent with the greater recalcitrance of the higher molecular weight polynuclear aromatic compounds.

For further information on any of the SITE Program projects, contact Ronald Lewis at FTS 684-7856 or 513-569-7856.



Bioremediation Report on Obstacles to Implementation

A report identifying key obstacles encountered in implementing bioremediation and approaches to addressing these obstacles is now available through the AgBiotech Center at Cook College, Rutgers, The State University of New Jersey. The report, *Utilizing Bioremediation Technologies: Difficulties and Approaches,* was generated by a national workshop involving 55 experts in bioremediation from around the country. The report is intended to provide a common ground for discussion among consulting engineers, potentially responsible parties, service providers, government regulators, and others deciding on the use of bioremediation.

The workshop at which this report was generated, "Translating Laboratory Results into the Field: Difficulties and Recommendations," brought together experts from industry, academia, and government, representing a mix of perspectives from researchers in the laboratory to engineers in the field.

Some of the key issues highlighted by the report include:

- The need for more integrated efforts across disciplines in the assessment and implementation of bioremediation
- The importance of developing scientifically based criteria and standards for initial site characterization, biotreatability assessments, and techniques for monitoring progress
- The need to build a data base of information and expand methods for data sharing to increase the predictability of future bioremediation efforts

In addition to presenting general issues for consideration when initiating a bioremediation project, the report offers a checklist of practical suggestions for avoiding problems and offsetting factors that may hinder successful implementation at a particular site. For example, it identifies factors that may need to be addressed at the time of site characterization and assessment, including physicochemical factors limiting biodegradation rates or causing toxicity to microbes, and approaches to overcome them.

The overall emphasis of the report is that the future of bioremediation depends upon the cooperation of experts in many disciplines and with differing perspectives working together to share experiences and establish good standard operating procedures. It calls for the expansion of a well-documented data-sharing network that includes the EPA's ATTIC data base, expert peer review of treatment plans and results, and publication in peer-reviewed journals of quantitative field experiments and process designs.

Sponsors of the national bioremediation workshop and the resultant report are the U.S. EPA Office of Environmental Engineering and Technology Demonstration and the Technology Innovation Office; the N.J. Department of Environmental Protection and Energy, Division of Science and Research; the U.S. Navy, Office of Naval Research; the National Institute of Environmental Health Sciences, Division of Extramural Research and Training; and Environment Canada's Biotechnology Section.

To obtain copies of the report at no charge, call 908-932-8165 (telefax, 908-932-6535) or write to Dr. Laura R. Meagher, AgBiotech Center, Cook College, Rutgers, The State University of New Jersey, P.O. Box 231, New Brunswick, NJ 08903-0231.

RSKERL Increases Bioremediation Research and Technical Assistance at Superfund and RCRA Sites

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Research Programs

RSKERL TSC technical assistance is inextricably linked to RSKERL research programs. Research scientists play a continuing role in shaping technical assistance responses, and the TSC Core Team actively participates in field-oriented research demonstrations. The exchange of staff and ideas between the two groups has assured that the TSC's technical assistance represents the latest in technology, and the experience gained through technical assistance provides guidance in the selection of timely and high-priority research initiatives.

In providing technical assistance at hazardous waste sites, TSC scientists and engineers provide a readily available and consistent source of interdisciplinary support not available elsewhere for evaluation and treatment of the subsurface. This assistance also assures that research results are transferred to the user community as rapidly as possible.

More information about the RSKERL Technology Support Center may be obtained by contacting Don Draper at 405-332-8800 or FTS 743-2202, or by writing to RSKERL, P.O. Box 1198, Ada, OK 74820.

Conference Highlights

Symposium on Bioremediation of Hazardous Wastes: U.S. EPA's Biosystems Technology Development Program

The U.S. Environmental Protection Agency's (EPA's) Biosystems Technology Development Program will have its Annual Symposium on Bioremediation of Hazardous Wastes on May 5-7, 1992. The symposium will be held in Chicago, Illinois, at the Holiday Inn Mart Plaza. At this meeting, members of the Biosystems Technology Development Program will review the research, development, and full-scale applications of bioremediation projects undertaken in 1991. Presentations will be on in situ treatment of the subsurface and surface and ex situ treatment of aqueous and gaseous phases and soils.

This year's event will bring together leading researchers and field personnel in bioremediation from federal, state, and local agencies; industry; vendors; contractors; and academia. Presenters will share data and recent research through poster displays and oral presentations on:

- Site Characterization
- Performance Evaluation
- Bioremediation Field Initiative
- Field Research
- Pilot-Scale Research
- Modeling
- Process Research

Registration

There is no fee to register for this symposium. To register, please call the Registration Hotline at 617-648-7811. If you would like further information about the symposium, please contact Kristin McCarthy at 617-641-5383.

All individuals on the mailing list for *Bioremediation in the Field* will receive registration information, an agenda, and hotel information by the end of March.

Subsurface Restoration Conference

The Subsurface Restoration Conference on June 21-24, 1992, is being sponsored by two EPA organizations—the R.S. Kerr Environmental Research Laboratory and the Technology Innovation Office—and four national research centers—the National Center for Ground-Water Research, the Western Region Hazardous Waste Research Center, the Waterloo Center for Ground-Water Research, and the Energy and Environmental Systems Institute.

Thirty-seven invited speakers representing the forefront of research and technology in subsurface restoration will present state-of-the-art assessments in the following categories: Regulatory Strategy; Basic Science Required for Decision-Making; Site Characterization; Contaminant Immobilization and Containment; Technologies for Contaminant Removal; Technologies for Contaminant Destruction; and Overview of Applicable Science, Technology, and Research Directions.

Those interested in this event should include researchers and regulators in ground-water protection and remediation; engineers developing technology related to subsurface contamination; site owners, environmental managers, and professionals from waste-generating industries; and ground-water consultants and vendors of equipment, manpower, and computer software.

Selected *exhibits* and *poster presentations* will be featured to illustrate the current state of science and technology in subsurface restoration and to promote information transfer.

The conference is being held at the Doubletree Hotel - Lincoln Centre in Dallas, Texas. To receive information on registration, poster presentations, or exhibitor booths, please call 713-285-5429 or write to Katherine Balshaw-Biddle at Rice University, Env. Sci. & Engr., P.O. Box 1892, Houston, TX 77251.

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, California. 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 (telefax 215-542-8567).

EPA Reviews New Rules for Microorganisms Under TSCA Section 5

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Distinguishing between commercial and noncommercial purposes once a product has proceeded beyond research and development (R&D) is not a problem. However, determining which activities constitute commercial R&D and are thus subject to the biotechnology rule is more difficult, in large part due to the increasingly complex financial arrangements developing between industry and academia. Because of the complexity of this issue, EPA is proposing three alternative interpretations of commercial R&D for microorganisms and seeking additional public comment to assist in establishing a definition for the final rule.

Scope of Microorganisms Covered

The fact that a microorganism is potentially subject to TSCA does not necessarily mean that it will be regulated under TSCA section 5. Only a new microorganism triggers PMN reporting just as a new chemical substance does. A microorganism is not new if it is listed on the TSCA Inventory of chemicals manufactured in the United States. In 1986, EPA stated that naturally occurring microorganisms would not be considered new and would implicitly be included on the Inventory, because they occur naturally and are derived through limited human intervention. New microorganisms were defined in the 1986 policy statement, as intergeneric microorganisms, i.e., those that contain genetic material from organisms of different genera. This definition of new microorganisms will continue to trigger PMN reporting until final rules are published.

The draft rules propose a different scope for new microorganisms by considering new microorganisms to be those that contain deliberately modified hereditary traits, and thus are most likely to exhibit novel behaviors. Microorganisms would not be considered new, however, and would be implicitly included on the Inventory if they occur naturally or contain deliberately modified hereditary traits that fall into one of EPA's four exclusion categories. These exclusions include those microorganisms that exhibit behavior likely to be found in nature. The rationale for these exclusions is discussed in detail in the June 1991 draft proposal. In 1986, EPA also stated its intention to supplement PMN requirements by requiring significant new use reporting for certain nonagricultural releases of pathogens and asked for voluntary reporting of these uses. While this remains as interim policy, EPA has dropped this approach in the draft proposed rules.

Full Reporting for General Commercial Use

The non-R&D or market level stage is referred to as general commercial use. For new microorganisms, notices must be filed with EPA 90 days prior to beginning manufacturing or importing, just as in the PMN program for traditional chemicals. Because different data requirements are specified for microorganisms, the draft proposed rules give the notice a new name: the Microbial Commercial Activity Notice, or MCAN. According to the rule, an MCAN must be filed for new microorganisms or significant new uses of microorganisms.

Exemptions for General Commercial Use

Just as in the New Chemicals Program, the draft proposal includes provisions for test marketing exemptions as well as the exemptions under TSCA section 5(h)(4). EPA is proposing exemptions from MCAN reporting for certain microorganisms that are well known and have a history of safe use. The Tier I exemption, which would not require EPA review, would be a one-time certification of compliance with all exemption criteria before the first use of the microorganism. The Tier II exemption would require filing a Tier II exemption request 45 days before beginning to manufacture or import the microorganism. For both the Tier I and Tier II exemptions, eligible recipient microorganisms would be listed in the regulations. In addition, introduced genetic material would have to meet specific criteria, and certain containment criteria would be specified for the Tier I exemption and serve as guidance for the Tier II exemption.

Coverage of R&D Activities

The greatest difference between the programs for traditional chemicals and for microorganisms is in the area of R&D. TSCA section 5(h)(3) allows EPA to exempt R&D activities involving chemical substances produced in small quantities. While this definition is fine for specified quantities of chemicals, it cannot be applied with the same expectations to living microorganisms, which have the ability to multiply and spread. EPA feels it is important to screen R&D releases of new microorganisms to address potential problems before releases occur on a larger scale. For this reason, in the new rules, EPA is distinguishing between R&D activities involving microorganisms released to the environment and those used under containment conditions.

EPA plans to maintain an R&D exemption for microorganisms used in contained structures, with structure defined broadly enough to encompass greenhouses and bioreactors. Like the R&D exemption for chemicals, exempt R&D activities must be conducted under the supervision of a technically qualified individual (TQI), who is required to document the containment and inactivation controls selected and used.

Reporting R&D Activities

Research involving intentional testing of microorganisms in the environment will not be eligible for the contained structures exemption. However, because R&D releases occur at a smaller scale than non-R&D

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EPA Reviews New Rules for Microorganisms Under TSCA Section 5

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releases, EPA has developed an abbreviated screening process for R&D releases called the TSCA Experimental Release Application (TERA). The review period for TERA is 60 days, because it focuses on a specific R&D activity, as opposed to the MCAN review, which must consider large-scale releases for general commercial use.

Some R&D activities for the contained structures exemption may be subject to the authority of another federal agency in addition to EPA. Where there is overlapping jurisdiction for R&D activities, EPA proposes to defer to the other federal agency if the researchers are receiving funding from that other agency. Researchers who are voluntarily complying with the NIH Guidelines would not be eligible for this deferral. For R&D activities that would require submission of a TERA, EPA proposes to enter into a Memorandum of Understanding (MOU) with each federal agency with which it may share jurisdiction. Each MOU will specify how EPA and the other agency will handle the overlapping authority.

EPA is also proposing an R&D exemption for released microorganisms with which EPA has gained familiarity through reviews. The exemption would be similar to the tiered exemptions, in that it would specify the recipient microorganism, the introduced genetic material, and the conditions of use.

Persons who are unsure as to whether their microorganisms would be subject to reporting under TSCA section 5 should consult with EPA before preparing any submission. A June 21, 1991, draft of the proposed rules was made available to the public as part of a package of material prepared for a meeting of EPA's Biotechnology Science Advisory Committee (BSAC), which was held on July 22, 1991. The June 21, 1991, draft proposal and the *Federal Register* notice describing EPA's current policy (51 FR 23313, June 26, 1986) are available from EPA's TSCA Hotline at 202-554-1404. For further information about the draft proposed TSCA biotechnology rules, contact Ellie Clark at 202-260-3402 or FTS 260-3402. For further information about submitting a PMN for a microorganism under EPA's current program, contact Kathleen Bailey at 202-260-5591 or FTS 260-5591.

Update on the Bioremediation Field Initiative

(Continued from page 1)

Seven 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; and Public Service and Electric, Denver, Colorado.

At the Eielson Air Force Base, the strategy for actively warming the soil by applying warm water at a low rate has been successful in maintaining the temperature above 10°C while temperatures in the control with no heating dropped to below 0° C. Bioventing at these temperatures has yielded measured biodegradation rates three times higher in the actively warmed area than in the control.

In the first half of the year, in situ respirometry tests will be conducted at the Hill Air Force Base site to measure in situ biodegradation rates in a bioventing evaluation. Also an inert gas tracer study will be conducted to evaluate the effectiveness of delivering air to the entire site.

Preliminary results from a field treatability study at the Brookhaven Wood Preserving Facility showed combined removals from 81 to 85 percent over an 8-week period using white rot fungi. The highest removals were 92 to 96 percent for three-ring aromatics. Removal rates were 80 to 84 percent for four- or more-ring aromatics and 81 to 86 percent for PCP.

Preliminary performance data on the fixed film bioreactor at the Libby Wood Preserving Facility indicate PAH removal from 80 to 90 percent and PCP removal from 40 to 80 percent. An increase in the hydraulic retention time from 10 to 15 minutes strongly influenced the removal rates of both PCP and the PAHs.

At the Allied site, additional ground-water sampling transects are planned for this spring. These data will provide information on the natural reductive dechlorination capacity at field scale.

Remediation is expected to be initiated in April at the Park City site. Initial site characterization has been completed and the engineering infrastructure installed.

For the Public Service site, coring to support the retrospective performance evaluation is scheduled for early summer and exposure modeling is to be completed by the end of the summer.

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

EPA Bioremediation Publications

To order EPA documents, call 513-569-7562 or FTS 684-7562. For NTIS documents, call 1-800-553-6847.

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	EPA/600/8-89/073
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 fromUnderground 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	EPA/600/2-91/010
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	EPA/600/J-91/243
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 Hazardous Waste	EPA/600/9-90/041
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	EPA/540/2-91/013a
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 ChlorinatedAromatic 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

FIELD APPLICATIONS OF BIOREMEDIATION[1]

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	PROBLEMS
I	Baird & McGuire** Holbrook, MA CERCLA Fund Lead	David Lederer (617) 573-5738 (FTS) 833-1738 Evelyn Tapahi (617) 556-1125	Ground water: pesticides (chlordane), creosote, BTEX. Volume: 200 gpm.	Operational: full scale. Remediation start: June 1990. Remediation expected completion: March 1992.	Ground water: MCLs	Ground water: continuous flow reactor, aerobic conditions, exogenous organisms, activated sludge. Other technologies: chemical extraction. Soil: incineration.	None
I	Charles George Landfill** Tyngsboro, MA CERCLA Fund Lead	Dave Dickerson (617) 573-5735 Dale Young (617) 292-5785	Ground water: BTEX, solvents, pesticides (chlordane), dioxin, arsenic. Volume: ultimately, 30 gpm ground water and leachate.	Predesign. Remediation expected start: 1994. Remediation expected completion: 2020.	Ground water: arsenic, 30 $\mu g/L$; benzene, 5 $\mu g/L$	Ground water and leachate: aerobic conditions, exogenous organisms, activated sludge with metals precipitation; carbon filtering and preaeration being considered.	None
I	Charlestown Navy Yard Boston NHP National Park Service Boston, MA CERCLA State Lead	Stephen Carlson (617) 242-5680	Sediments: PAHs, creosote	In design: laboratory scale. Planning pilot scale for FY 1992.	Not yet established	Aerobic attached growth process, anaerobic attached growth process, and in situ treatment of sediments being considered.	None
I	Coakley Landfill North Hampton, NH CERCLA Enforcement Lead	Steve Calder (617) 573-9626 Dan Coughlin (617) 573-9620	Ground water: ammonia, BOD. Volume: 100 gallons per hour.	Predesign. Remediation expected start: 1994. Remediation expected completion: 2000.	Ground water: ammonia, NPDES requirements	Biotreatment. Other technologies: treatment train (metal precipitation, air stripping). Ground-water treatment: source control about 50%.	None
I	General Electric (Woods Pond)** Pittsfield, MA RCRA Lead (Federal)	Joan Blake (202) 260-6236 (FTS) 260-6236	Pond/river sediments: PCBs. Volume: 250 gallons of sediment and water.	Predesign: pilot scale since May 1991.	Sediments: PCBs, 2 ppm per peak	In situ bioremediation. Other technologies: bioreactor and flotation separation, incineration.	None
I	General Electric** Pittsfield, MA TSCA Lead (Federal)	Joan Blake (202) 260-6236 (FTS) 260-6236	Soil and river sediments: PCBs. Volume: 12 cu. m.	Operational: November 1990.	Sediments: PCBs, 2 ppm per peak	Batch reactor flow. Other technologies: flotation separation, incineration.	None
I	Hamilton Standard** Windsor Locks, CT RCRA Lead (Federal)	Gina Snyder (617) 573-9674 (FTS) 833-1874 Fred Johnson (203) 728-6595 Scot Frost (HSD) (203) 654-3843	Soil: PCBs, petroleum hydrocarbons	Planning to conduct treatability studies in FY 1992.	Not yet established	In situ bioremediation.	None
I	Iron Horse Park Billerica, MA CERCLA Enforcement Lead	Don McElroy (617) 223-5571	Soil/sludges: petroleum hydrocarbons, PAHs. Volume: 20K+ cu. yd.	Operational: full scale. Remediation start: October 1991. Remediation expected completion: 1996.	Soil: PAHs, less than 1 ppm	Solid-phase bioremediation: excavate to treatment cell—surface treatment; land farming within treatment cell—optimizing natural indigenous microbes. 10% to 20% of site under bioremediation.	Effective operation occurs only in warm seasons.

[1]CERCLA/RCRA/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	PROBLEMS
I	Pine Street Canal** Burlington, VT CERCLA Fund Lead	Ross Gilleland (617) 573-5766 (FTS) 833-1766 Michael Jasinski (617) 573-5786 (FTS) 833-1786	Ground water/soils/sediments: PAHs, VOCs, BTEX, cyanide. Volume: 100K cu. yd. to 800K cu. yd.	Predesign. Treatability study started July 1990 and completed May 1991.	Not yet established	Soil: in situ bioremediation and solvent extraction. Ground water: aerobic attached growth process (fixed film reactor). Other technologies: solidification, incineration, oil/water separation, metals removal by slag, carbon adsorption, solvent extractions.	None
I	Sylvester** Nashua, NH CERCLA State Lead	Chet Janowski (617) 573-9623 (FTS) 833-1623 Paul Hiertzler (603) 882-3631	Ground water: phenols, MEK, acetone, toluene, benzene, vinyl chloride, chloroform. Volume (ground water): 3K gpm by air stripping, 50 gpm by activated sludge.	Operational: full scale. Remediation start: June 1986. Remediation expected completion: July 1994. Costs: $2.5M per year.	State of NH drinking studies	Activated sludge biotreatment with extended aeration. Other technologies: vacuum extraction.	Difficulty in providing sufficient nutrients to maintain an active biomass.
II	American Linen** Stillwater, NY State Enforcement Lead	Frank Peduto NYSDEC (518) 371-9153	Soil: BTEX, PAHs, VOCs, VTX. Volume: 4,375 cu. yd.	Operational: full scale. Start: July 1991. Expected completion: Fall 1992. Bioremediation of first lift section complete; preparation beginning for second lift.	TCLP extract compared to meet soil guidance levels	Solid-phase bioremediation. Contaminated soil is applied in 2-ft layer; nutrients are added and soil is tilled by mechanical means. 100% of site under bioremediation.	None
II	FAA Technical Center** Atlantic County, NJ CERCLA Enforcement Lead	Carla Struble (212) 264-4595 (FTS) 264-4595 Keith Buch (FAA) (609) 494-6644 Joseph Freudenberg (609) 633-1455	Soil/ground water/floating product: JP-4 jet fuel, BTEX-naphthalene, phenols. Volume: 360K gals. of free product. Volume (soil): 33,000 cu. yd.	In design: laboratory scale. Design expected completion: Spring 1992. Remediation expected start: Summer 1992. Expected capital cost: $286K. O&M cost: $200K.	Soil: NJ Soil Action Level; NJ MCLs for drinking water	In situ bioremediation. Other technologies: free product extraction, cement kiln incineration, and addition of nutrients for subsequent reinjection; soil venting; off-gas treatment with catalytic incinerator combustion or activated carbon absorption of VOCs.	None
II	General Electric** Hudson River TSCA Lead (Federal)	Jim Harrington Ajay Shroff NYSDEC (518) 485-8792 William Ports (518) 457-5677	River sediments: PCBs. Volume: 150 cu. ft.	Predesign: laboratory scale. Treatability study. Expected cost: $2.6M.	Not yet established	In situ bioremediation, aerobic conditions, indigenous organisms, sequencing batch reactors.	PCB degradation
II	General Motors - Central Foundry Division Massena, NY CERCLA Enforcement Lead	Lisa Carson (212) 264-6857 (FTS) 264-6857	Soil/sludge/sediment: PCBs. Volume: 350K cu. yd.	Predesign. Treatability studies: laboratory scale. Several full-scale treatments being considered. Expected start: April 1993.	Soil: 10 mg/kg PCBs. Sediments: 1 ppm PCBs. Sludge: 10 ppm PCBs.	Sequencing batch reactors; slurry phase bioremediation. Other technologies: chemical extraction, thermal desorption, and chemical treatment will be considered in the event that bioremediation is unsuccessful.	Oil and grease in samples is hindering efficiency of bioremediation; material may require pretreatment.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	PROBLEMS
II	Knispel Construction Site Horseheads, NY UST Lead (State)	Frank Peduto NYSDEC (518) 371-9153	Soil/ground water: BTEX, gasoline. Site area: 200 ft^2; volume (ground water): 10 ft. shallow.	Remediation start: January 1989. Remediation completed: October 1989. Cost: $250K+ with 1-4 years of pump and treat.	Ground water: BTEX, 5 ppb. Soil: BTEX, 5 ppb. Drinking water standards.	In situ bioremediation. Infiltration trench used to inject nutrients and hydrogen pyroxide. Three 80 gpm recovery wells used to draw nutrients and H_2O_2 through contaminated zone.	None
II	Mobil Terminal Buffalo, NY CERCLA Enforcement Lead	Robert Leary Mike Hinton (716) 851-7220 Frank Peduto NYSDEC (518) 371-9153	Soil: gasoline, BTEX, PAH, VOC. Volume: 2 acre bioremediation cell, approximately 5K cu. yd.	Operational: full scale since July 1991.	Soil (excavated): BTEX, PAH, VOC - NYSDEC guidance values, based on TCLP.	Solid-phase bioremediation, aerobic conditions, exogenous organisms; contaminated soil removed when clean and placed on adjacent property. Other technologies: vacuum extraction added April 1991. 100% of site under bioremediation.	None
II	Nascolite** Millville, NJ CERCLA Fund Lead	Farnaz Saghafi (212) 264-4665 (FTS) 264-4665 Pat Evangelista (212) 264-6311 (FTS) 264-6311 Anton Mawarajah (609) 633-6798	Ground water: volatiles, methylmethacrylate, semivolatiles. Volume: all underlying ground water under biotreatment.	Predesign. Treatability studies on soil completed September 1990; studies on ground water underway. Remediation expected start: September 1993. Remediation expected completion: January 1996.	NJ Interim Soil Action Levels for methylmethacrylate: 350 ppb (ground water)	Ground water: rotating biological contactor; source of microorganisms not yet determined. Other technologies: solidification/stabilization of site soils contaminated with lead.	None
II	Osmose** Buffalo, NY CERCLA State Lead	Jim Harrington Ajay Shroff NYSDEC (518) 485-8792	Soil: creosote, fuel oil. Volume: 670 cu. yd.	Operational: full scale. Remediation start: September 1990. Expected costs: $125K.	Not yet established	Solid-phase bioremediation. 30% of site under bioremediation.	None
II	Plattsburgh AFB* Plattsburgh, NY Federal Facility	Phil Von Bargen (518) 565-6672 Jim Lister (518) 457-3976	Ground water: petroleum	Predesign: possible pilot scale. Remediation expected start: March 1994.	Not yet established	In situ bioremediation, bioventing.	None
II	Syracuse** Syracuse, NY UST Lead (State)	Harry Warner (315) 426-7519	Soil: petroleum hydrocarbons, jet fuel. Volume: 5 to 6K cu. yd.	Operational: full scale. First phase: started July 1990; completed Spring 1991. Second phase: started Spring 1991. Site was prepared for closure Fall 1991, but small untreated areas were discovered. Material has been separated and moved to an adjacent area for treatment in Spring 1992.	NY Soil Cleanup Levels	Solid-phase bioremediation: soil removal at other half of site.	Late start for first phase; cold weather slowed use of bioremediation.
III	ARC Gainesville, VA RCRA Lead (Federal)	Robert Stroud (215) 597-6688 (FTS) 597-8214	Soil: chlorobenzene. Volume: 2K cu. yd.	Completed: full scale. Started October 1989. Completed June 1991.	Soil: chlorobenzene, 0.014 ppm	Bioaugmentation aboveground, bioventing. Other technologies: pump and treat, possibly soil shredding. 5% 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	PROBLEMS
III	Atlantic Wood Portsmouth, VA CERCLA Enforcement Lead	Drew Lausch (215) 597-1286 (FTS) 597-1286	Soil/sediments: PCP, PAH from wood preserving, dioxins (furans)	Predesign: RI/FS ongoing. ROD start date: 2nd quarter FY 1992.	Not yet established	Soil/sediments: solid-phase bioremediation. Other technologies being considered: soil washing, thermal desorption, incineration.	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 (FTS) 597-9023	Ground water: arsenic, zinc, lead, carbon disulfide, hydrosulfide, phenol, cadmium	In design. Expected start: 4th quarter of 1992. Expected cost: $9M.	0.05 mg/L arsenic; 5 mg/L zinc; 0.05 mg/L lead; 0.7 mg/L carbon disulfide; 0.3 mg/L phenol; 0.01 mg/L cadmium; not established for hydrosulfide	Biological and chemical wastewater treatment.	None
III	Drake Chemical Lock Haven, PA CERCLA Fund Lead	Roy Schrock (215) 597-0517 (FTS) 597-0517	Soil/ground water: pesticides, DCE, fenac (herbicide)	Predesign: laboratory scale. Start: May 1991. Expected completion: April 1992.	Not yet established	Aerobic attached growth.	None
III	L.A. Clarke & Son** VA CERCLA Enforcement Lead	Gene Wingert (215) 597-1727 (FTS) 597-1727	Soil/sediments: creosote. Volume: 119K cu. yd.	In design: pilot scale. Started: November 1991. Expected installation: 1992. Cost: $23M for entire site.	Not yet established	Soil: in situ bioremediation; creosote recovery. Other technologies: soil flushing. 25% of site under bioremediation.	None
III	Ordnance Works Disposal Area WV CERCLA Enforcement Lead	Drew Lausch (215) 597-1286 (FTS) 597-1286	Soil: carcinogenic PAHs. Volume: Approx. 42K cu. yd.	Predesign: treatability studies planned. RD start date: August 1990. Expected completion: March 1993. Planning laboratory scale. Unilateral administrative order issued June 1990. Expected cost $8.3 M.	Carcinogenic PAHs, 44.7 ppm	Solid-phase bioremediation. Other technologies: solidification of inorganics.	None
III	Whitmore Labs** Myerstown, PA CERCLA Fund Lead	Christopher Corbett (215) 597-6906 Noreen Chamberlain (717) 657-6309	Soil/ground water/sludges: arsenic, aniline, still bottom wastes (only certain soils are targeted for bioremediation). Volume: 4K cu. yd.	Predesign. Limited treatability study completed June 1990. Remediation expected start: June 1993. Negotiation with PRPs continuing.	Arsenic above background levels. Saturated soils (mg/kg): benzene, 0.002; trichloroethene, 0.004; tetrachloroethene, 0.012; aniline, 0.002. Unsaturated soils (mg/kg): benzene, 0.009; trichloroethene, 0.017; tetrachloroethene, 0.051; aniline, 0.009.	Biological treatment (treated soils will be disposed of off site). Other technologies: chemical treatment. Less than 10% of site under bioremediation.	None
IV	Alabama State Docks** Mobile, AL RCRA Lead (Federal)/soil RCRA Lead (State)/ground water	Nancy Bethune (404) 347-3433 (FTS) 257-3433 Clyde Sherer (205) 271-7726	Ground water/soil: PCP, creosote	Predesign: full scale. State RCRA permit (GW) issued 9/13/91. In situ phased implementation 2/5/93. Federal RCRA (HSWA) permit issued 9/13/91. RCRA facility investigation (source/soil) 1/21/92.	Ground water: chromium, 0.05 mg/L; arsenic, 0.05 mg/L; benzene, 0.005 mg/L; MDL for all others continuing. Soil cleanup levels have not yet been established.	Ground water: aerobic attached growth process for creosote, and in situ bioremediation for both PCP and creosote. Soil: solid-phase bioremediation. Slurry-phase bioremediation may be used if levels are low enough. 100% of the site is 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	PROBLEMS
IV	American Creosote Works Jackson, TN CERCLA Fund Lead O.U. #1	Tony DeAngelo (404) 347-7791 (FTS) 257-7791 Ron Sells (901) 423-6600	Soil: creosote	Predesign.	100 ppm for 6-8 indicators	Not yet established	Remedial action contingent upon receiving 10% cost share from state. Funds available for treatability studies only.
	O.U. #2**		Ground water: creosote, PCP, solvents. 2-3 feet of product in monitoring wells.	Predesign. Hydrogeologic investigation underway. Remediation expected start: December 1995. Expected completion: December 1998.	100 ppm for 6-8 indicators	Not yet established. 20% of site under bioremediation.	
	O.U. #3		Soil/sludge: creosote. Volume: 50K+ cu. yd. with 50K+ cu. yd. later.	Predesign. Partial removal of sludges (creosote) and highly contaminated soils for offsite incineration has occurred. Still no feasibility studies.	100 ppm for 6-8 indicators	Solid-phase bioremediation: aerobic conditions, indigenous organisms, dealing with process area contained soils and "fixed" creosote sludges in a large capped lagoon. 50% of site under bioremediation.	
IV	American Creosote Works** Pensacola, FL CERCLA Fund Lead	Madolyn Streng (404) 347-2643 (FTS) 257-2643 Beverly Houston (404) 347-3866 Charles Logan (904) 488-0190	Soil: creosote, PAHs, PCP, dioxin. Volume: 20,000 cu. yd.	In design: pilot scale. Remediation expected start: October 1992. Remediation expected completion: September 1994. Expected cost: $5M.	Soil: PCP, 30 mg/kg; PAHs, 50 mg/kg; dioxin on site, 2.5 μg/kg; dioxin off site, 1.0 μg/kg	Soil: slurry-phase bioremediation. Other technologies: incineration being considered for dioxin-contaminated soils.	Bioremediation not effective for remediation of dioxins in soils.
IV	Brookhaven Wood Preserving* Brookhaven, MS CERCLA Fund Lead	Art Smith (404) 347-3931 (FTS) 257-3931	Soil: creosote, PCP	Predesign: pilot scale. Field scale demonstration test. Remediation expected start: May 1993. Expected completion: May 1994.	Not yet established	Land treatment with aerobic growth conditions and indigenous and exogenous organisms.	Lack of information on use of white rot fungus at field-scale level. Field treatability study does show reduction of PCP and creosote: 86% and 96%, respectively.
IV	Brown Wood Preserving** Live Oaks, FL CERCLA Enforcement Lead	Martha Berry (404) 347-2643 (FTS) 257-2643 Charles Logan (904) 488-0190	Soil: creosote, PAHs, PCP, dioxins. Volume: 9K cu. yd.	Completed. Full scale and monitored for 3 yrs. Remediation start: October 1988. Remediation completed: December 1991.	Soil: 100 ppm PAHs	Solid-phase bioremediation: surface treatment lined with clay berms 5-6 ft.	None
IV	Cabot Koppers** Gainesville, FL CERCLA Enforcement Lead	Martha Berry (404) 347-2643 (FTS) 257-2643 Kelsey Helton (904) 488-0190	Soil: PAHs; organics (phenols, naphthalene, fluorine, pyrene, pentachlorophenol, etc.); metals (arsenic, chromium). Volume: 6,700 cu. yd.	In design: full scale. Design work plan started: April 1991.	Carcinogenic PAHs, 0.59 ppm; organics: phenols, 4.28 ppm; naphthalenes, 211 ppm; fluorine, 323 ppm; PCP, 2.92 ppm; metals: arsenic, 27 ppm; chromium, 92.7 ppm.	In situ bioremediation. Other technologies: soil washing with bioremediation or solidification. 50% 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	PROBLEMS
IV	Cape Fear Wood Preserving Fayetteville, NC CERCLA Fund Lead	Jon Bornholm (404) 347-7791 (FTS) 347-7791	Soil/ground water/surface water/sediments: PAHs, arsenic, creosote, chromium. Volume: 2K to 4K cu. yd.	Predesign. Laboratory treatability studies completed. ESD issued, capacity assurance issue to be resolved. Pilot scale work is needed to confirm effectiveness; overall results suggest that a longer incubation period could result in further reduction of PAHs to below cleanup goals.	Soil (mg/kg): arsenic, 94; carcinogenic PAHs, 2.5; total PAHs, 100 ppm; chromium, 88 ppm. Ground water (μg/L): carcinogenic PAHs, 10; noncarcinogenic, 14,350. Surface water: arsenic, 12 μg/L. Sediments (mg/kg): arsenic, 94; total PAHs, 3.	Sequencing batch reactor; preceded by soil washing, possibly solidification.	Study was terminated due to time constraints.
IV	Carolawn** Carolawn, SC CERCLA Enforcement Lead	Al Cherry (404) 347-7791 (FTS) 347-7791	Ground water: VOCs	Predesign. Partial consent decree issued 12/4/91. Bench-scale studies begun 12/16/91. UV oxidation treatability studies needed to determine potential for treatment of contaminated ground water. Permit application for construction of observation wells has been made.	Acetone, 710 μg/L; cis-DCE, 70 μg/L; trans-DCE, 120 μg/L; TCA, 200 μg/L; TCE, 5 μg/L; Pb, 5 μg/L	Not yet established	None
IV	Celanese Fibers Operations** Shelby, NC CERCLA Enforcement Lead	Ken Mallary (404) 347-7791 (FTS) 257-7791 Charlotte Jesneck (919) 733-2801	Ground water: ethylene glycol, benzene, acetone, chromium. Soil: chromium, antimony, PAHs, acetone. Sediments: bis(2-ethylhexyl)phthalate, PAHs. Volume (soil): 2K cu. yd.	Treatability studies complete. Bioreactor on-line since August 1989. Remediation expected completion: September 1999.	State of North Carolina MCLs; all RCRA constituents; both state and federal levels	Sequencing batch reactor. In addition to bioremediation, carbon adsorption and air stripping are used for ground-water remediation.	Biomass upsets decreasing operating efficiency of treatment system. Cause of upset 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 (FTS) 257-2643	Soil/ground water/sediments: petroleum, PCPs, dioxins. Volume: 27K cu. yd.	In design: September 1990 to June 1992. Laboratory scale with pilot study planned. Remediation expected start: September 1992. Remediation expected completion: March 1994. Expected cost: $8.6M.	Soil/sediments: 25 ppm. Ground water: 1 ppm.	Slurry-phase bioremediation in treatment train: soil washing, bioremediation, solid stabilization. Landfill: 100% under bioremediation. Operations: 50% under bioremediation.	Wood chip removal from soils. Bioremediation was found to be ineffective for dioxins.
IV	Dubose Oil Cantonment, FL CERCLA Enforcement Lead	Mike McKibben (404) 347-2643	Soil: PCP, oil. Volume: 15K cu. yd.	Predesign. Currently in technology selection phase. Pilot study before design. Remediation expected start: December 1992. Remediation expected completion: March 1995. Expected cost: $3M.	50 mg/kg total TPNA; 50 mg/kg PCPs; 1.5 mg/kg xylene; 10 mg/kg benzene; 0.05 mg/kg TCE; 0.07 mg/kg PCE	Solid-phase bioremediation. Other technologies: carbon adsorption. Approx. 90% of the site will be bioremediated.	Pilot study was delayed due to waiting for the results of a dioxin test.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	PROBLEMS
IV	Koppers/Florence Florence, SC RCRA Lead (Federal)	Mike Arnett (404) 347-7603 (FTS) 257-7603	Soil: PCPs, PAHs	Predesign started March 1, 1991.	Not yet established	Soil: In situ bioremediation, land treatment. Other technologies: ground-water extraction, pretreatment, discharge to a POTW. 33% of site under bioremediation.	None
IV	Langdale Facility Sweetwater, TN RCRA Lead	Charles Burroughs (615) 741-3424	Soils/sludges: creosote (K001 waste)	Installation. Contaminated soil and sludge excavated. Site capped after biotreatment.	Not yet established	Solid-phase bioremediation: land treatment using bacteria, nutrients, and cometabolite.	None
IV	Shavers Farm Shelby County, GA CERCLA Fund Lead	Chuck Eger (404) 347-3931 (FTS) 257-3931	Soil: dicamba, benzoic acid, dichlorosalicyclic acid, benzonitrile	Predesign. Pilot bench-scale treatability studies being reviewed. Work plans in place.	25 ppm for all constituents	Undetermined	None
IV	Southeastern Wood Preserving* MS CERCLA Fund Lead	Don Rigger (404) 347-3931 (FTS) 257-3931	Soil: creosote	Operational: full scale since April 1990. Expected completion: April 1993. Expected cost: $1.7 M.	Not yet established	Slurry batch-flow reactor. Aerobic growth conditions; indigenous and exogenous organisms. Other technologies: soil washing.	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 (Federal)/soil RCRA Lead (State)/ground water	Pat Anderson (404) 347-3433 (FTS) 257-3433	Ground water/soil: PCP, creosote. Volume (soil): 1 acre with uncertain depth. Volume (ground water): 5 acres with contaminated plume.	Predesign: full scale	Not yet established	Solid-phase bioremediation on soil; sequencing batch reactor on ground water. Considering slurry-phase bioremediation. 100% of the site under bioremediation.	None
IV	White House Waste White House, FL CERCLA Fund Lead	Tony Best (404) 347-2643 (FTS) 257-2643	Ground water/soil/sediments: acids, PCB, waste oil, creosote. Volume: 56,900 cu. yd.	Predesign. Laboratory scale completed. Expected start of design: April 1992. Remediation expected start: March 1993. Remediation expected completion: March 1995. Expected cost: $18.9M.	Not yet established	Slurry reactor, continuous flow, completely mixed. Treatment train: soil washing, bioremediation, solid stabilization. 100% under bioremediation.	None
V	Allied Chemical** Ironton, OH CERCLA Enforcement Lead	Jim Van der Kloot (312) 353-9309 (FTS) 353-9309 Kay Gossett (614) 385-8501	Lagoon sediments: PAHs. Volume: 500K cu. yd.	Predesign. Pilot studies: April-Summer 1992. Enhance bioavailability through use of surfactants, and facilitate the delivery of oxygen to the waste matrix. Incurred cost for testing: >$2M. Expected cost: $20M.	Soils/waste: 1 to 100 mg/kg total carcinogenic PAHs; target level 1 mg/kg; risk based	In situ PAH bioremediation and prepared pad bioremediation. Other technologies: incineration with onsite reuse of waste heat (waste fuel recovery); ground-water pump and treat. 10% of site under bioremediation.	Currently experiencing difficulties delivering oxygen to sediments. Lab work underway to increase bioavailability of PAHs.
V	Allied Signal/Bendix** St. Joseph, MI CERCLA Enforcement Lead	John Kuhns (FTS) 353-6556 Sally Beebe (517) 373-4110	Ground water: TCE, DCE, VC	Predesign. Treatability study to be completed June 1992. Laboratory scale and pilot scale. Remediation expected start: late 1993. Remediation expected completion: 1998.	Not yet established	In situ bioremediation: using indigenous methantrophs. 75% of site under bioremediation.	Recent sampling has identified high 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	PROBLEMS
V	Aristech Chemicals** Haverhill, OH RCRA Lead (Federal)	Matt Ohl (312) 886-4442 Bob Volkmar (614) 533-5412 Scott Schermerhorn (614) 385-8501	Soil: cumene, phenols. Volume: 140 ft of drainage ditches.	Operational: full scale. Remediation start: July 1991. Incurred cost: $180K. Expected cost: $258K.	Phenol, 4.1 mg/kg; cumene, 4.67 mg/kg; health risk based	In situ bioremediation. Indigenous and exogenous bacteria are tilled into the soil. More than 1% (only drainage ditch areas) is under bioremediation.	Excessive soil moisture
V	Autostyle Kentwood, MI State Lead	Bonnie White (616) 456-5071	Ground water/soils: solvents, aromatic ketones, alcohol. Volume: 15-20 gpm.	Operational: full scale since September 1990.	Not yet established	Aerobic attached growth process; submerged fixed film reactor. Other technologies: vacuum extraction, soil vapor extraction for product recovery and soil treatment. 100% of ground water at site is under bioremediation.	None
V	B&F Trucking Company** Rochester, MN UST Lead (State)	Pat Hanson (612) 297-8578 Stephen Thompson (612) 297-8603	Soil/ground water: BTEX, gasoline. Volume: 700 cu. yd.	Operational: full scale. Remediation start: April 1991; additional equipment needs to be installed. Remediation expected completion: December 1992. Incurred cost: $341K. Expected cost: $20K.	Soil: BTEX, 50 mg/kg. Ground water: BTEX, 100 x MN Dept. of Health RALs.	In situ soil bioremediation; external bioreactor. 75% of site under bioremediation.	Increase in iron concentration in ground water is causing iron bacteria and resulting in the accumulation of "slime" on the surface of pipes and other process equipment.
V	BP Oil Company** Lima, OH RCRA Lead (Federal)	Jerry Grammas (419) 226-2592 Gary Vanderembse (419) 226-2744	Soil: petroleum	Predesign: full scale study underway. Remediation expected start: 1992.	Not yet established	Solid-phase bioremediation	Land treatment unit permit denied.
V	Burlington Northern MN CERCLA State Lead	Tony Rutter (312) 886-8961 (FTS) 886-8961 Fred Jenness (612) 297-8470	Soil/ground water: oil, carcinogenic and non-carcinogenic PAHs, creosote. Volume: 10K cu. yd.	Operational: full scale since 1987. Expected completion: 1995. Incurred cost: $725K. Expected costs of O&M: $38.6K per year for 30 years.	Ground water: carcinogens, 28 mg/L; noncarcinogens, 300 mg/L. Soil: detoxification levels.	Treatment train: in situ and solid phase bioremediation. Other technologies: thermal desorption, ground-water monitoring. 20% of the 4-acre site under bioremediation.	Degradation rate is longer than expected for the more complex contaminants.
V	Cliff/Dow Disposal Site MI CERCLA Enforcement Lead	Lida Tan (312) 886-1842 (FTS) 886-1842 Bruce Van Ottern (517) 373-8427	Soil/ground water: wood tar, acetic acid, phenol, PAHs	Predesign: laboratory scale. Actual start: November 1991.	Not yet established	In situ forced aeration. 10% of site under bioremediation.	Volume increase (100%); temperature control.
V	Fisher-Calo LaPorte, IN CERCLA Fund Lead	Brad Bradley (312) 886-4742 (FTS) 886-4742	Soil/ground water: TCE, DCE, DCA, PCBs	Design: laboratory scale.	5 ppb TCE; 70 ppb DCE; 200 ppb DCE; drinking water standards used where possible	Undetermined. 1% of site may be under bioremediation.	None
V	Galesburg/Koppers IL CERCLA State Lead	Brad Bradley (312) 886-4742 (FTS) 886-4742 Steve Davis (212) 785-3913	Soil: phenols, chlorophenol, PNAs, PCP, PAHs	Predesign. Expected start date: late 1992.	Not yet established	Solid-phase bioremediation; in situ with amendments. 100% of soil at site will be bioremediated.	None

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

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V	Hentchells Traverse City, MI UST Lead (State)	Ann Emington (616) 775-9729	Ground water/soil: BTEX	Completed. Full scale started September 1985. Completed: March 1989. Pursuing final cleanup of residue at leading edge of plume. Also need soil verification.	Nondetection levels	Closed loop in situ bioremediation. Enhancing microbial growth through addition of ammonium chloride, monosodium phosphate, disodium phosphate, and oxygen to ground water.	Iron-forming bacteria clogging carbon system.
V	Joliet Army Ammunition Plant** Elwood, IL Federal Facility	Dion Novak (312) 886-4737 Steve Miller (217) 782-1803	Soil: TNT, DNT, RDX. Area: 10 acres.	Predesign: solid-phase treatment. In design for slurry-phase work plan. Pilot scale. Remediation expected start: April 1992. Remediation expected completion: December 1992.	Not yet established	Soil: slurry batch reactor and land treatment with aerobic, exogenous organisms. Approx. 10 out of 23,040 acres under bioremediation in pilot program.	None
V	Joslyn MFG** Brooklyn Center, MN CERCLA State Lead	John Betcher 612) 296-7821 Kevin Turner (312) 886-4444 (FTS) 886-4444	Soil: PAHs, PCP. Volume: 67K cu. yd.	Operational: full scale. Remediation start: August 1989. Expected completion: September 1992.	Soil: 100 ppm total PAHs; 150 ppm total PCP; dermal contact standards	Solid-phase bioremediation. 10-acre land treatment unit. Other technologies: ground-water pump and treat. 35% of site undergoing bioremediation.	Extreme rainfall in May 1991 caused flooding and delayed treatment of lift 2 soil.
V	Marathon Station-Ervines Kentwood, MI State Lead	Bonnie White (616) 456-5071	Ground water: BTEX, gasoline. Volume: 3-5 gpm	Operational: full scale. Remediation start date: 1988.	Ground water: gasoline (background nondetection levels or risk-based levels)	Aerobic attached growth process; submerged fixed film. Other technologies: carbon polish unit to ensure compliance with NPDES permit. 95% of captured ground water at site is under bioremediation.	System was designed as a decay phase reactor, so periodically has to shut down to allow regrowth of cultures; only occurred once.
V	Mayville Fire Department** Mayville, MI UST Lead	Jon Mayes (517) 684-9141	Soil/ground water: BTEX	Operational	Soil: 10 ppb BTEX. Ground water: 1 ppb BTEX.	Bioremediation using oxygen with no addition of nutrients.	None
V	McGillis Gibb** MN CERCLA Fund Lead	Daryl Owens (312) 886-7089	Ground water: PAHs, PCP	Predesign. Treatability studies and pilot completed December 1989. Full scale. Remediation expected start: March 1993. Remediation expected completion: November 1995. Cost for Phase 1: $600K to $800K. Full scale bioremedation system tested under the SITE program.	Not yet established. POTW pretreatment standards.	Ground water: aerobic attached growth process; fixed film. Other technologies: soil washing and soil incineration under consideration.	None
V	Moss American** Milwaukee, WI CERCLA Enforcement Lead	Betty Lavis (312) 886-4784 (FTS) 886-4784	Soil/sediments: creosote. Volume: 86,500 cu. yd.	Operational. Pilot scale to begin: Summer 1992. Remediation start date: June 1991. Remediation expected completion: 1994.	Soil/sediment: creosote, 6.1 ppm	Slurry-phase bioremediation: bioreactor using indigenous bacteria. Other technologies: soil washing.	Clay content may reduce efficiency of system. High molecular weight PAHs. Surfactants may interfere with bio slurry system.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	PROBLEMS
V	New Lyme Landfill** New Lyme, OH CERCLA Fund Lead	Ted Smith (312) 353-6571	Ground water: ethyl benzene, methylene chloride	Operational: conducted pilot-scale study in January 1988. Remediation start: November 1991. Expected cost: $5M to $6M.	Ground water: ethyl benzene, 68 $\mu g/L$; methylene chloride, 473 $\mu g/L$; phthalate, 9.2 $\mu g/L$.	Ground water: rotating biological reactors, fixed film. 100% of the site under bioremediation.	Calcium carbonate precipitation causing plugging. Fungi entering with influent causing plugging.
V	Onalaska Municipal Landfill** LaCrosse County, WI CERCLA Fund Lead	Kevin Adler (312) 886-7078 Robin Schmidt (608) 267-7569 Paul Kogol (608) 264-6013	Soil: naphthalene, BTEX. Volume: 5,000 cu. yd.	Predesign: laboratory scale. Treatability studies: October 1991 to March 1992. Remediation expected start: Summer 1992. Remediation expected completion: Fall 1993. Expected cost: $1.2M.	Not yet established	In situ bioremediation. Other technologies: ground-water pump and treat. 3 of 11 acres under bioremediation. 20% of site will undergo bioremediation.	Adjacent landfill generates CH_4.
V	Organic Chemical MI CERCLA Fund Lead	Tom Williams (312) 886-6157	Ground water: oil, TCE, toluene	Predesign: started February 1992. Waiting for feasibility study to do remediation on TCE and toluene. Working on additional work plan for oil. Ground-water pump and treat expected start: September 1992.	Not yet established	Pump and treat as interim action until levels of organics are reduced.	Dioxin in the soil precluded bench scale testing by EPA.
V	Parke-Davis** Holland, MI RCRA Lead (Federal)	Shari Kolak (312) 886-6151 Dave Slayton (517) 373-8012	Soil/ground water: BTEX, solvents, benzene, methanol, isopropanol, fuel	Predesign	Not yet established	Undetermined	None
V	Rasmussen Livingston County, MI CERCLA Enforcement Lead	Ken Glatz (312) 886-1434 Denise Gruben (517) 335-3386	Ground water: acetone, HETP, 2-butanone, isophorone, 2-methylphenol, 4-methylpentanone	Predesign	Ground water: acetone, 700 ppb; 2-butanone, 350 ppb; 4-methyl-2-pentanone, 350 ppb	Considering pump and treat air stripping/carbon absorption treatment with added microorganisms and nutrients; fixed film reactor, immobilized. Other technologies: chemical treatment and air stripping. 100% of site under bioremediation.	None
V	Reilly Tar & Chemical St. Louis Park, MN CERCLA Enforcement Lead	Daryl Owens (312) 886-7089 (FTS) 886-7089 Doug Beckwith (612) 296-7715 Mike Scott (612) 296-7297	Soil: PAHs Ground water: creosote	Predesign: laboratory scale. Treatability study start: September 1991. T.S. expected completion: September/October 1993. Expected cost for treatability studies: $140K.	Not yet established	Soil: in situ bioremediation; surface and subsurface; using additional nutrients (N,P). Ground water: pump and treat with discharge to POTW. Other technologies: carbon adsorption.	None
V	Reilly Tar** IN CERCLA Enforcement Lead	Dion Novak (312) 886-4737	Ground water: benzene, ammonia, pyridine. Volume: 1.6 mgd extraction system.	Predesign: laboratory scale. Will probably not select bioremediation as a viable technology. May be used on source area remediation at a later date.	Not yet established	Ground water: sequencing batch reactor, continuous flow. 100% of site under bioremediation.	60 to 80 ft. of aquifer with conductivities of 10^{-2} minus 10^{-3} with interfingering until units are not continuous.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	PROBLEMS
V	Seymour Recycling IN CERCLA Enforcement Lead Unit 1	Jeff Gore (312) 886-6552 (FTS) 886-6552	Ground water: VC, TCE, DCE, benzene, chloroethane. Volume: 500K gallons.	Operational: full scale. Remediation start: June 1991. Expected completion date: 1996. Incurred cost: $1M. Expected cost: $1M.	VC, TCE, DCE: drinking water standards	In situ bioremediation: VC, TCE, DCE. Other technologies: vacuum extraction, chemical treatment.	None
	Unit 2		Soil: VC, TCE, DCE. Volume: 111K cu. yd.	Operational: full scale. Remediation start: June 1991. Remediation expected completion: 1993. Incurred cost: $750K. Expected cost: $500K.	Not yet established	In situ bioremediation. Other technologies: vacuum extraction.	None
V	Sheboygan River and Harbor** Sheboygan, WI CERCLA Enforcement Lead	Bonnie Eleder (312) 886-4885 (FTS) 886-4885	Sediments: PCBs. Volume: 2,700 cu. yd. in capped disposal facility. Approximately 10K lb PCB.	Pilot scale since mid-1989. Pilot scale expected completion: December 1992.	Not yet established	In situ bioremediation: capped sediments; natural and enhanced biodegradation in enclosed structure. Contained treatment facility with possibly aerobic and anaerobic conditions. Other technologies: chemical extraction and treatment, thermal desorption, sediment capping.	Delays in pilot study due to additional bench-scale tests to determine how to enhance the pilot study.
V	Sleeping Bear Dunes National Lakeshore** Empire, MI Federal Facility	John Wilson (405) 332-8800 (FTS) 743-2011 Guy Sewell (405) 332-8800	Ground water: gasoline. Volume: 1K gal.	Operational: full scale. Start: February 1991. Expected completion: February 1992.	Not yet established	Soil: in situ bioremediation, passive natural bioremediation. 100% of site under treatment.	An excess of isomers.
V	Speigelberg Landfill Livingston Township, MI CERCLA Enforcement Lead	Ken Glatz (312) 886-1434 Denise Gruben (517) 335-3386	Ground water: 2-butanone, 2-hexanone. Volume: 140K cu. yd.	Predesign.	Ground water: 2-butanone, 350 ppb; 2-hexanone, 50 ppb	Pump and treat, air stripping/carbon adsorption treatment with added microorganisms and nutrients. 100% of site considered for bioremediation.	None
V	St. Louis River Interlake/Duluth Tar Site** Duluth, MN CERCLA State Lead	Debbie Siebers (312) 353-9299 (FTS) 353-9299	Soils/sediments: VOCs, PAHs	Predesign. Remedial investigation/feasibility study. Remediation expected start: 1993.	Not yet established	Undetermined	None
V	Union Carbide** OH CERCLA Enforcement Lead	Kathleen Warren (312) 353-6756 Terry Roundtree (312) 353-3236	Soil/ground water: VOCs, dioxin, mono- and dichlorinated biphenyls, PCBs	Predesign: laboratory scale. Treatability study report being reviewed.	Not yet established	Ground water: activated sludge. Soil: in situ biomediation. Other technologies: GAC.	None
V	Upjohn Company Portage Facility* Kalamazoo, MI RCRA Lead (Federal)	Lorna Jereza (312) 353-5110 (FTS) 353-5110 Greg Rudloff (312) 353-4788 (312) 886-0455	Soil/ground water: solvents	Predesign: pilot scale since 1987.	Not yet established	Ground water: fixed film biomass with continuous flow reactor, aerobic growth conditions, indigenous organisms.	Low winter temperatures

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	PROBLEMS
V	West K&L Avenue Landfill** Kalamazoo, MI CERCLA Enforcement Lead	Dan Cozza (312) 886-7252	Ground water: (organics) acetone, benzene, vinyl chloride, toluene, xylene, trans-1,2-DCE, ethylbenzene, 1,1-dichlorethane, 1,2-dichloroethene	In design: October 1991. Expected installation: 1993. Expected operational start date: 1994. Consent decree still being worked out. Expected cost: $2.2M.	Acetone and 1,1-dichlorethane, 700 ppb; benzene, 1.0 ppb; 1,2-dichloroethane, 0.4 ppb; vinyl chloride, 0.02 ppb; xylene, 20 ppb; toluene, 40 ppb; trans-1,2-DCC, 100 ppb; ethylbenzene, 30 ppb	Aerobic attached growth process. Other technologies: depending on the results of ground-water samples during the pump test, precipitation of metals, and a carbon filter for the vinyl chloride may need to be added.	Treatment of vinyl chloride, handling of water after treatment, no POTW (possible with installation of 3 miles of sewer line), no surface water discharge available, need to reinject.
VI	Atchinson Santa Fe, NM CERCLA Enforcement Lead	Susan Webster (214) 655-6730 (FTS) 255-6730	Soil/sludge: hydrocarbons, diesel. Volume: 28K cu. yd.	Installation completed: November 1991. Remediation expected start: April 1992. Pilot scale. Expected costs: $3M.	Not yet established	In situ and combined bioprocesses: surface and subsurface, sludges treated separately. 100% of the site under bioremediation.	High chloride content in soil and sludges.
VI	French Limited Crosby, TX CERCLA Enforcement Lead	Judy Black (214) 655-6735 (FTS) 655-6735	Sludges: organics, metals, PCBs	Installation. Remediation expected start: February 1992. Remediation expected completion: February 1996. Expected cost: $81M.	Sludges: BAP, 9 ppm; PCB, 23 ppm; VOCs, 43 ppm; arsenic, 7 ppm; benzene, 14 ppm	Sludges: treatment in an aerated lagoon. Other technologies: stabilization of residues. 100% of site under bioremediation.	None
VI	Hudson Refining Company Cushing, OK RCRA Lead (Federal)	Keith Phillips (214) 655-6480 (FTS) 255-6480 Brent Troskowski (214) 655-6480 (FTS) 255-6480	Soil/ground water: oil, grease, hydrocarbons, PAHs, benzene. Volume: 145,500 cu. yd.	Operational: full scale since April 1988.	Ground water: 30% to 50% reduction of contaminants through ground-water recovery system	Solid-phase bioremediation of 40% of site (three phases): (1) active; requires monthly application of nutrients and monthly tilling; (2) enhanced: annual application of nutrients and no tilling; (3) augmented: no addition of nutrients or tilling.	Lack of microorganisms; state order failed to specify cleanup levels; recontamination at nearby refinery.
VI	North Cavalcade St.** Houston, TX CERCLA State Lead	Deborah Griswold Larry Wright (214) 655-6715 (FTS) 255-6715 Louis Rogers (512) 463-8188	Ground water: carcinogenic PAHs, benzene. Soil: creosote, carcinogenic PAHs. Volume (soil): 5,500 cu. yd. above 10 ft.	In design: pilot scale since March 1991. Remediation expected start: October 1993. Expected completion: September 1996. Expected cost: $3.2M.	Soils: benzene, 0.04 ppm; carcinogenic PAHs, 1 ppm	Land treatment, composting: PAHs in soil, aerobic conditions, indigenous organisms. Other technologies: pump and treat with carbon adsorption of ground water. 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 (FTS) 255-6710 Sandra Greenwich (504) 765-0487	Soil/sludge: petroleum, hydrocarbons. Volume (sludge): 600K gallons. Volume (soil): 200K cu. yd.	Installation: full scale. Remediation expected start: April 1992. Remediation expected completion: 1997 to 1999. Supplemental ground water RI being conducted. Construction of land treatment unit complete. Waste application expected Spring 1992, following award of contract. Incurred costs: $5.4M.	Not yet established; expected to have standard discharge requirements; objective is to reduce contaminant concentration from 76% to 4%.	Solid-phase bioremediation. Other technologies: GAC. 70% of site under bioremediation.	None

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VI	Sheridan Disposal Services** Houston, TX CERCLA Enforcement Lead	Ruth Izraeli (214) 655-6735 (FTS) 255-6735	Soil/sludge/surface water: benzene, toluene, ethyl benzene, phenol, PCBs	In design. Pilot study completed; report due April 1992. Preliminary findings are hopeful. Remediation expected start: 1993. Remediation expected completion: 1996. Expected cost: $28M.	Soil/sludge/surface water: PCBs, 25 ppm (PCBs as an indicator of other organics)	Slurry-phase bioremediation: aqueous bioreactor. Other technologies: stabilization of residues.	None
VII	Amoco Refinery Sugar Creek, MO RCRA Lead (State)	Frank Dolan (314) 751-3176 Alan Hancock (913) 551-7647	Soil/sludge: K049, K050, K051, oil, PAHs, refinery sludges, metals. Volume: 137K cu. yd at 27% to 40% oil and grease.	Operational: full scale. Remediation start: July 1990. Remediation expected completion: 1999. Expected cost: $23.5M.	Total PAHs, less than 300 mg/kg; potentially carcinogenic PAHs, less than 300 mg/kg	Soil/sludge: solid-phase bioremediation; sequencing batch reactors. 5% of site under bioremediation.	Material handling problems related to siting the facility and the rate of reaction in the full scale; oxygen transfer has been slower than expected. Temperature effects in aeration pond being monitored.
VII	Conservation Chemical Kansas City, MO CERCLA Enforcement Lead	Steve Auchterlonie (913) 551-7778 (FTS) 276-7778	Ground water: phenols, VOCs, semivolatiles. Volume: 150-200 gpm for approx. 30 years.	Operational: full scale. Remediation started: April 1990. Incurred costs: $110K.	Missouri drinking water standards	Aerobic attached growth process: fixed film bioreactor (2 in series). Other technologies: treatment train (carbon adsorption, lime precipitation, sulfide precipitation). 100% of ground water at site is under remediation.	None
VII	Fairfield Coal & Gas** Fairfield, IA CERCLA Enforcement Lead	Steven Jones (913) 551-7755 (FTS) 276-7755 Johanshir Golchin (515) 281-8925	Ground water/soil: PAHs, BTEX, benzene	Operational: pilot scale since January 1992. Expected cost for construction: $149K. Additional $1.5M if fully implemented.	Ground water: benzene, 1 ppb; carcinogenic PAHs, 0.2 ppb. Soil: benzene, 241 ppm; PAHs, 500 ppm; carcinogenic PAHs, 100 ppm.	Ground water: in situ bioremediation (subsurface) via injection wells, aerobic conditions, indigenous organisms. Other technologies: thermal treatment of contaminant source areas; pump and treat for ground water using carbon adsorption with polymer injection and settling.	Possible future problems due to poor transmissivity of the aquifer.
VII	International Paper** Joplin, MO RCRA Lead (State)	Frank Dolan (314) 751-3176 Bob Stewart (913) 551-7654	Soil: 24 organic constituents from creosote, including PAHs, PCP. Volume: 70,000 cu. yd.	Operational: pilot scale and full scale. Remediation expected start: June 1992. Remediation expected completion: 2005. Expected cost: $9.5M.	Soil: sum of the concentrations of 24 aromatic compounds is less than 600 mg/kg.	Soil: solid-phase bioremediation; in situ soil flushing, aerobic conditions, indigenous organisms. Other technologies: chemical treatment. 20% of site under bioremediation.	Bioremediation failed at this 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 severely limit cleanup options.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	PROBLEMS
VII	Park City KA State Lead	John Wilson (405) 332-8800 (FTS) 743-2011 Lonnie Kennedy (405) 332-8800	Ground water: benzene, BTEX. Volume: 700K cu. ft. contaminated aquifer (actual volume will be larger).	Installation: since September 1991. Full scale. Remediation expected start: Jan.-Feb. 1992. Remediation expected completion: February 1993. Incurred cost: $275K. Expected cost: $650K.	Ground water: benzene, 5 µg/L BTEX, drinking water standards	Ground water: in situ bioremediation. Other technologies: in situ soil flushing; denitrification of BTEX; possibly bioventing.	Delays due to site serving as a test case for new Kansas environmental regulations.
VII	Scott Lumber** Alton, MO CERCLA Fund Lead	Bruce Morrison (913) 551-5000 (FTS) 276-3881	Soil: creosote compounds (PAHs, benzo-a-pyrene). Volume: 15,900 tons.	Completed: full scale. Remediation start: June 1990. Completed: December 1991. Cost: $1.3M.	500 ppm, total PAHs; 14 ppm benzo-a-pyrene	Solid-phase bioremediation. 75% of site was bioremediated.	None
VII	Vogel Paint & Wax** Maurice, IA CERCLA State Lead	Steven Jones (913) 551-7755 (FTS) 276-7755 Bob Drustrup (515) 281-8900	Soil: BTEX, MEK, organic hydrocarbons, leachable organics. Volume: 10K cu. yd.	Operational: full scale since October 1991. Cost: $2M.	Soil: organic hydro-carbons, 100 mg/kg; leachable organics, TCLP test	Solid-phase (land treatment), aerobic conditions, exogenous organisms. Other technologies: air stripping of contaminated ground water.	Volatilization control/air monitoring being evaluated.
VIII	Burlington Northern** Somers, MT CERCLA Enforcement Lead	Jim Harris (406) 449-5414 (FTS) 585-5414	Soil: PAHs, zinc, phenol. Ground water: PAHs. Volume (soil): solid-phase: 12K cu. yd.; in situ: 70K cu. yd.	In design: 3Q/92. Expected installation: 1Q/93. Expected operational: 1Q/93. Pilot scale. Expected start: 3Q/92. Expected completion: 5-10 years from start. Expected cost: $11M.	Soil: PAHs, 36 mg/kg. Ground water: carcinogenic PAHs, 0.030 µg/L.	Soil: solid-phase bioremediation, aerobic conditions, indigenous organisms. Sediment and ground water: in situ bioremediation. Other technologies: in situ soil flushing. 80% of site under bioremediation.	Pilot-scale field activities have been initiated because of low soil transmissivities.
VIII	Burlington Northern* Glendive, MT Water Quality Bureau	Terry Webster (406) 444-2406	Soil: creosote, BTEX, petroleum, solvents	Operational: full scale. Remediation start: 1991.	Soil: diesel, 100 ppm	Ex situ land treatment, aerobic growth conditions, indigenous organisms; active tillage, moisture and nutrient control; seasonal monitoring of contaminants. Monitoring below treatment zone 1/year for leaching.	None
VIII	Conoco Landfarm* Billings, MT RCRA Lead (State)	Mark Hall (406) 444-4096	Soil/sludge: BTEX, K051, K048 (metals, organics).	Operational: full scale. Remediation start: 1973. Expected completion: 2010.	Metals: <1,000 ppm Organics: <pqls	Ex situ land treatment by aerobic microbial decomposition, indigenous organisms. Other technologies: chemical adsorption, ion exchange, precipitation.	None
VIII	Exxon Landfarm* Billings, MT RCRA Lead (State)	Mark Hall (406) 444-4096	Soil/sludge: BTEX, K049, K050, K051 (metals, organics).	Operational: full scale. Remediation start: 1980. Expected completion: 2013.	Metals: <1,000 ppm Organics: <pqls	Ex situ land treatment by aerobic microbial decomposition, indigenous organisms. Other technologies: chemical adsorption, ion exchange, precipitation.	None
VIII	Hill AFB* CO Federal Facility	Robert Stites (303) 294-1974	Soil: JP4 jet fuel.	Operational: full scale.	Not yet established	Bioventing. 100% of site under remediation.	None

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	PROBLEMS
VIII	Idaho Pole Company* Bozeman, MT CERCLA State Lead	Jim Harris (406) 449-5414 Janie Stiles (406) 449-4067 Kevin Kirley (406) 449-4067	Soil/sediments/ground water: PCP, PAHs, dioxins/furans.	Predesign: since September 1991. Remediation expected start: 1993.	Not yet established	Soil: ex situ land treatment and in situ soil with fixed film biomass and slurry reactor. Ground water: in situ microbial treatment.	Presence of dioxins/furans.
VIII	Joliet Weed Control* Miles City Airport, MT CERCLA State Lead	Carol Fox (406) 449-4067	Soil: pesticides: 2,4,5-t; 2,4-d; dioxin; arsenic.	Predesign: laboratory and pilot scale. Treatability studies expected start: June 1992. Expected completion: January 1993. Contract for studies not yet signed.	Not yet established	Treatment not yet determined.	Lengthy contracting process.
VIII	Libby Ground-Water Site** Libby, MT CERCLA Enforcement Lead	Jim Harris (406) 449-5414 (FTS) 585-5414	Soil/ground water: PAHs, PCPs. Volume (soil): 45K cu. yd.	Operational: full scale. Land treatment unit: since May 1991. Phase I and bioreactor for upper aquifer ground water: since October 1991. Installed: solid-phase unit cell #2. Incurred cost: $4M.	Soil: 88 mg/kg, total carcinogenic PAHs; 8 ppm, non-carcinogenic PAHs; 7.3 ppm, pyrene; 37 mg/kg, PCP; 1 ppb, dioxin; 8 mg/kg, naphthalene; 7.3 mg/kg, pyrene. Ground water: 400 $\mu g/L$, carcinogenic PAHs; 40 $\mu g/L$, non-carcinogenic PAHs; 1.05 mg/L PCP; 5 mg/L, benzene; 50 mg/L, arsenic; other compounds, not greater than 10^{-5}.	Soil: solid-phase bioremediation. Ground water: in situ bioremediation and aerobic attached growth process (fixed film reactor).	Oil-water separation in bioreactor. Pyrene degradation rates in land treatment units for soils.
VIII	Montana Pole* MT CERCLA Federal Lead	Brian Antonolli (406) 449-4067	Soil: PCP, PAHs, dioxins/furans	Predesign. RI/FS in progress. ROD expected in March 1993. Negotiations with PRPs expected in August or September 1993.	Not yet established	Treatment not yet determined.	Presence of dioxins/furans.
VIII	Montana Rail Link* East Helena, MT Water Quality Bureau	Terry Webster (406) 444-2406	Soil: creosote, BTEX, petroleum, solvents	Operational. Remediation expected start: May 1992.	Soil: diesel, 100 ppm	Ex situ land treatment with 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) 444-2406	Soil: creosote, BTEX, petroleum, solvents	Operational. Remediation expected start: May 1992.	Soil: petroleum, 100 ppm	Ex situ land treatment with indigenous organisms. Land tillage, moisture and nutrient control, seasonal monitoring for leachate below treatment zone.	None

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	PROBLEMS
VIII	Public Service** Denver, CO UST Lead (State)	Suzanne Stevenson (303) 293-1511 (FTS) 330-1511 Lisa Weer (303) 331-4830	Soil/ground water: petroleum, benzene, xylene, toluene. Volume: 5,921,330 gals per year.	Operational: full scale. Remediation start: June 1989. Expected completion: 1992. Incurred cost: $500K.	Not yet established, risk assessment based	In situ bioremediation, combined bioprocess: nutrient gallery reinjection/pump recovery wells. Other technologies: chemical treatment.	A Risk Assessment has been submitted to the State of Colorado Health Dept. for review, along with an application for closure.
VIII	Union Pacific Laramie, WY RCRA Lead (Federal)	Felix Flechas (303) 293-1524	Soil/ground water: creosote and PAHs/PCP. Volume (soil): 750K cu. yd. Volume (creosote in soil): 6M gallons.	Predesign. Feasibility study: 1985-June 1992. Pilot scale completed: September 1990. Recovery of dense nonaqueous phase liquids start: Fall 1991. Expected completion: 1996. Incurred costs: $50M. Expected costs: $100M.	Not yet established	Soil: solid-phase and in situ bioremediation; considering slurry-phase bioremediation. Ground water: aerobic attached growth process (fixed film reactor) and sequencing batch reactor, pond bottoms. Other technologies being considered: chemical extraction, in situ soil flushing, soil washing, chemical treatment, thermal desorption. 50% of site under bioremediation.	Fluid delivery and therefore bioremediation is not uniform.
IX	BKK Landfill West Covina, CA RCRA Lead (Federal)	Carmen Santos (415) 744-2037 (FTS) 484-2037 Nancy Lindsay (415) 744-2038 (FTS) 484-2038 Glenn Heyman (415) 744-2044 (FTS) 484-2044	Ground water: chromium, vinyl chloride, dichloromethane, chloroform, 1-2 dichloropropane, carbon tetrachloride, TCE, benzene, phenol, toluene, cyanide, heavy metals (arsenic, cadmium, lead, mercury)	Operational: full scale since 1987. Interim remedial study in progress.	Not yet established	Slurry-phase bioremediation; treatment plant with PACT system, which combines activated sludge and carbon adsorption. Other technologies: metal removal system using complexation with EDTA, chemical treatment, chlorination.	Tried to delist effluent for beneficial reuse. Other alternatives being evaluated.
IX	CAL TRANS Lakeport & Garberville, CA UST Lead (State)	Ken Smarkel (916) 322-3910 John Wesnousky (916) 324-1807	Soil: oil (petroleum hydrocarbons). Volume: 70 cu. yd.	Completed: full scale. Remediation start: November 1988. Remediation completed: January 1989.	Oil (petroleum hydrocarbons), 100 ppm	Solid-phase bioremediation	Degradation rate is 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: diesel fuel (petroleum hydrocarbons)	Completed: full scale. Remediation start: May 1989. Remediation completed: August 1989.	Petroleum hydrocarbons, 100 ppm	Solid-phase bioremediation	None
IX	Converse/Montabello Corp. Yard Montabello, CA UST Lead (State)	Paul Hadley (916) 324-1807	Soil: gasoline, diesel	In design since January 1991. Pilot scale.	Not yet established	In situ bioremediation. Less than 10% of site is 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	PROBLEMS
IX	CWX Freight Lines Santa Rosa, CA UST Lead (State)	Mark Berscheid (916) 322-3294	Soil: diesel Volume: 600 cu. yd.	Operational: pilot scale. Bioremediation start: October 1990. Remediation completion: November 1991.	Not yet established	Combined bioprocesses: sprinkler system to apply bioculture formulation; collected leachate treated in an aerobic biological reactor before circulation. 100% of site undergoing bioremediation.	None
IX	Former Service Station Los Angeles, CA UST Lead (State)	Tony Palagyi (818) 505-2701 John Baldwin	Soil/ground water: total petroleum hydrocarbons, diesel, BTEX, benzene, gasoline. Volume (soil): 3K cu. yd. Volume (ground water): 800K gallons.	Completed. Remediation start: November 1988. Remediation completed: March 1991. Incurred costs: $1.6M.	Soil: total petroleum hydrocarbons, 100 ppm. Ground water: benzene, 5 ppb.	In situ bioremediation: closed loop system; hydrogen peroxide as oxygen source; aboveground holding tank for nutrient addition. Other technologies: in situ soil flushing, vacuum extraction. 65% of site under bioremediation.	During channeling, overload reduced the reinjection process rate.
IX	Fort Ord Army Base Monterey, CA CERCLA Enforcement Lead	John Chestnutt (415) 744-2387 Vance Fong (415) 744-2392	Soil: fuel hydrocarbons	Installation: pilot scale. Remediation expected completion: FY 1993.	Soil: not yet established. Ground water: MCLs.	Solid-phase bioremediation for MEK. Other technologies: pump and treat, carbon adsorption treatment.	None
IX	Growers Air Service/University of CA Davis, Medlock Field Woodland, CA TSCA Lead (State)	John Wesnousky (916) 322-2543 John Menke (916) 324-3773	Soil (pesticides): atrazine, BRAVO chlorothalonil, dacthal, thiadine 1 & 2, DDT, thiadine sulfate, trifluralin, methyl parathion, malathion, parathion, toxaphene, trithion, paroxon, methyl trithion, ethion.	Completed: October 1988. Report available.	Not yet established	In situ solid-phase bioremediation	None
IX	Harmon Field Tulare County, CA CERCLA State Lead	Tony Luan (916) 322-6872	Soil: 10 organic pesticides	Pilot project completed. Evaluating field study results.	Not yet established	Solid-phase bioremediation. Pilot-scale tests on 13, 5-gallon buckets of soil.	None
IX	Hercules Incorporated Hercules, CA CERCLA State Lead	Tony Luan (916) 322-6872	Soil: TNT, DNT, trinitrobenzene, nitrobenzene	Pilot project completed. Evaluating field study results.	TNT, 30 ppm; DNT, nitrobenzene, 5 ppm	Solid-phase bioremediation. Pilot-scale tests with 1 cu. yd. boxes of soil.	None

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	PROBLEMS
IX	J.H. Baxter** Weed, CA CERCLA Enforcement Lead	Elizabeth Keicher (415) 744-2361 (FTS) 484-2361 Jeff Rosenbloom (415) 744-2362 (FTS) 375-484-2362 Joan Fleck (707) 576-2220 Ed Cargile (916) 855-7858	Soil/ground water: benzene, PCP, PAHs. Volume: organic soils, 12,500 cu. yd.; mixed organic/inorganic, 9,375 cu. yd.	Predesign: pilot scale, expected March 1992. Expected installation: September 1993. Pilot scale. Remediation expected start: September 1993. Expected completion: September 1995. Expected cost: $1.9M.	Soil (mg/kg): arsenic, 8; chromium, 8; PCP, 17; carcinogenic PAHs, 0.51; dioxin, 0.001; furans, 0.001. Sediments (mg/kg): arsenic, 8; chromium, 18; zinc, 26; carcinogenic PAHs, 0.5; PCP, 1; TCP, 1. Leachate (mg/L): arsenic, 5; chromium, 5; PCP, 1.7; carinogenic PAHs, 0.005; non-carcinogenic PAHs, 0.15; dioxin, 0.001. Ground water (μg/L): arsenic, 5; chromium, 8; benzene, 1; PCP, 2.2; PAHs, 5; dioxin, 2.5 x 10^{-5}.	Soil: lined prepared bed biological unit. Ground water: fixed film bioreactor. Aerobic conditions, indigenous organisms. Approx. 33% of soil under bioremediation; 100% of ground water.	None
IX	JASCO Mt. View, CA CERCLA Fund Lead	Rose Marie Caraway (415) 744-2235	Soil/ground water: VOCs	Predesign. Treatability study being conducted while FS is on hold. Final FS will be produced following final treatability study. Laboratory scale. Lab treatment study cost: $30K.	Not yet established	Soil/ground water: solid-phase, in situ bioremediation. Composting technologies being evaluated in treatability study. 75% of site is under bioremediation.	None
IX	Koppers Co. Inc. Orville, CA CERCLA Enforcement Lead	Fred Schauffler (415) 744-2365 (FTS) 484-2365 Ed Cargile (916) 855-7858	Soil/ground water: arsenic, chromium, PCDD/PCDF, PAHs, PCPs. Volume (soil): 110K cu. yd.	Predesign: pilot scale. Remediation expected start: Fall 1992. Expected completion: May 1994. Demonstration, Phase 1, remediation expected completion: Spring 1994. Remediation, Phase 2, ongoing for 10+ years. Consent decree expected for RD/RA. Treatability studies to be done early 1992. Expected cost: $12.2M.	Soil: arsenic and chromium, background levels; PAHs, 0.19 mg/kg; PCP, 17 mg/kg; dioxins, 30 ppt. Ground water: arsenic and chromium, background levels; PAHs, 0.007 μg/L; PCP, 2.2 μg/L; dioxins, 0.53 ppq.	In situ bioremediation, aerobic conditions, indigenous organisms. Other technologies: soil washing, fixation of metal contaminated soil, ground-water pump and treat, and carbon adsorption treatment. 30% of site under bioremediation.	None
IX	Liquid Gold Richmond, CA CERCLA Enforcement Lead	Rose Marie Caraway (415) 744-2235	Soil/ground water: waste oils, metals (lead, zinc), phenol	Predesign. Site is in preliminary stages of considering bioremediation technology; no decisions have been made and start of a treatability study is not planned.	Not yet established	Not yet established	Metals contamination on site

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT	STATUS	CLEANUP LEVELS	TREATMENT	PROBLEMS
IX	Marine Corps Air/Ground Combat Center Twenty-Nine Palms, CA CERCLA Fund Lead	Rosalind Dimenstein (619) 346-7491	Soil: jet fuel, gasoline, diesel fuel, transmission fluid, aviation fluid	Design completed. Navy submitted final report to Department of Toxic Substances Control. Navy classified soil as nonhazardous waste and planned full-scale aboveground bioremediation.	Not yet established	Aboveground bioremediation system over a liner with leachate collection and induced air infiltration systems.	None
IX	Middle Mountain Silvex* Greenlee County, AZ Federal Facility	Robert Mandel (415) 744-2290 Tim Steele (602) 257-2335	Soil: silvex (2,4,5-TP, 2,4,5-T, 2,4-D). Volume: 550 cu. yd.	Operational: full scale. Remediation start: October 1991. Expected completion: October 1992. Incurred cost: $29K. Expected cost: $45K.	Soil: silvex, <50 mg/kg	Ex situ land treatment with indigenous organisms under aerobic growth conditions. Prepared bed with water and nutrients; periodic rototilling. Other technologies: photodegradation. 100% of site under bioremediation.	None
IX	Montrose Chemical Corp of California Torrance, CA CERCLA Enforcement Lead	Nancy Woo (415) 744-2394	Soil: DDT, monochlorobenzene	Predesign: pilot scale. Treatability study completed. Considering pilot scale test, feasibility study.	Not yet established	In situ bioremediation: land treatment; considering white rot fungus treatment.	None
IX	Protek Carson City, CA UST Lead (State)	Ken Smarkel (916) 322-3910 John Wesnousky (916) 324-1807	Soil: diesel fuel (petroleum hydrocarbons). Volume: 700 cu. yd.	Completed: full scale. Remediation start: August 1988. Completion: December 1989.	Diesel, <10 mg/kg	Solid-phase bioremediation. 100% of site under bioremediation.	The control cell, which did not receive any nutrient supplements, propriety inoculum, or the benefit of vigorous aeration, seemed as effective in reducing the contaminant level as the site.
IX	Romic Chemicals East Palo Alto, CA RCRA Lead (Federal)	Glenn Heyman (415) 744-2044 (FTS) 484-2044	Soil: toluene, PCE, xylene, MEK, VC, acetone. Ground water: acetone, DCE, toluene, VC, xylenes, MEK, MIBK, methylene chloride.	Predesign. Treatability studies: late FY 1992.	Not yet established	Soil: in situ bioremediation (under consideration). Ground water: aerobic attached growth process, in situ bioremediation, combined bioprocesses. Other technologies: vacuum extraction, activated carbon, UV peroxidation. 100% of site under bioremediation.	High total dissolved solids (Fe, Mn) 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 Main Street Facility San Diego, CA UST Lead (Federal)	Paul Hadley (916) 324-1807	Soil: gasoline. Volume: 1,200 cu. yd.	Operational: full scale since October 1989.	Not yet established	In situ bioremediation. 100% of site under bioremediation.	None
IX	Seaside High School Seaside, CA UST Lead (State)	Dick Eriksson (916) 322-7046 Alan Ingham	Soil: diesel fuel. Volume: 100 cu. yd.	Full scale bioremediation completed 1988. Diesel contaminated soil was successfully remediated and placed as a road-base material prior to paving.	Soil: diesel fuel, 500 mg/kg	Solid-phase bioremediation. 100% of the site was remediated.	None

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IX	SEGS Solar Project** Kramer Junction, CA State Lead	Bruce La Belle (916) 324-2958	Soil: biphenyl, diphenyl ether	Full scale. Operational since July 1990.	Soil: biphenyl, diphenyl ether, 1,000 mg/kg	Waste pile treatment	None
IX	Solvent Service** CA CERCLA State Lead site under RCRA authority	Ron Gervason (415) 464-0688 Marie Lacey (415) 744-2234 (FTS) 484-2234	Ground water: acetone, TCE, over 30 industrial solvents	Operational since January 1991. Full scale. Remediation expected completion: 2001. Incurred cost: $399K. Expected cost: $844K.	Ground water (µg/L): 1,2-DEC, 5; cis-1,2-DEC, 6; trans-1,2-DCE, 10; ethylbenzene, 400; 1,1,1-TCA, 200; Freon 113, 1200; benzene, 0.7; acetone, 400.0; 1,1-DEC, 1.0; naphthalene, 2000	Fixed film reactor. Other technologies: vacuum extraction; steam enhancement of vacuum extraction.	Permitting
IX	Southern California Edison Visalia, CA CERCLA State Lead	Richard Procunier (415) 744-2224	Ground water: PCP, VOCs	Predesign: RI/FS currently in progress.	Not yet established	Not yet established; considering bioremediation.	None
IX	Southern Pacific Transportation Co. SPTC Maintenance Yard Roseville, CA CERCLA State Lead	David Wright (916) 332-3910	Soil: hydrocarbons, diesel fuel. Volume: 240 tons.	Full scale bioremediation system completed: January 1991. Cost: $310K.	Soil: hydrocarbons, diesel fuel, 5000 mg/kg	Solid-phase bioremediation.	None
X	American Crossarm Chahailis, WA CERCLA Fund Lead	Lee Marshall (206) 553-2723 Mike Ruef (206) 438-3059	Soil: PCP, PAH, dioxin.	Predesign. Expected completion of feasibility studies: October 1992.	Not yet established	Not yet established	None
X	East 15th Street Service Station Anchorage, AK UST Lead (State)	Tony Palagyi (818) 505-2701	Soil: total petroleum hydrocarbons. Volume: 1,500 cu. yd.	In design. Installation expected: June 1992. Remediation expected start: June 1992. Remediation expected completion: June 1993. Cost incurred: $75K. Expected cost: $200K.	Soil: diesel, 100 ppm	In situ bioremediation; bioventing with monitoring of moisture, CO_2, and nitrates. 20% of site under bioremediation.	Winter weather
X	Utah Power and Light** Idaho Falls, ID RCRA Lead (State)	Andrew Pentony (208) 334-5898 Randy Steger (208) 334-5898	Soil: creosote. Volume: 725 sq. yd. (2-3 feet deep)	One site area completed October 1991; the other completed January 1992.	Soil: PAHs, 50 ppb	Soil: in situ bioremediation. Alternative cap. Other technologies: pump and treat for ground water. Approx. 33% of site under bioremediation.	No reference to volatilization, leaching, dilution of contaminants. No monitoring of ground-water addition, mixing, and drying. Preliminary tests were determined to be unsuccessful.

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X	Wyckoff Eagle Harbor Puget Sound, WA CERCLA Enforcement Lead	Rene Fuentes (206) 553-1599 (FTS) 399-1599 Lori Cohen (206) 553-6523 (FTS) 399-6523	Soil/ground water/surface water: creosote, PCPs.	Operational: full scale started January 1990.	Not yet established	Slurry-phase bioremediation: bioreactor-activated sludge for treatment of ground water; aerobic attached growth process in series with aeration tank, clarifier, and biological sludge digestor; possible soil and sludge bioremediation.	Insufficient data resulted from plant operation to determine ability of plant to increase its treatment rates. Total plant treatment rate (including carbon filters) ranges from 0-60 gpm. Some problems with biomass dying due to pentachlorophenol spikes.

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

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

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.

Bioventing—Air is injected into contaminated soil at rates low enough to increase soil oxygen concentrations and stimulate indigenous microbial activity.

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.

In Situ Soil, Ground Water, or Sediments—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.

Land Treatment—Contaminants are treated with microorganisms typically indigenous to the existing soil matrix; nutrients, moisture, and oxygen can be added to optimize growth conditions; clean soil is left on site.

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.

*Indicates a new site.

**Indicates the site has been updated or includes new information.

Shading indicates a non-CERCLA site.

BAC Discusses Mission, Accomplishments, and Goals at February Meeting

(Continued from page 4)

Tests are currently under way to evaluate 10 commercial products.

- The establishment of a Bioremediation Products Evaluation Center (BPEC) by NETAC. The Center will be active in future validation of protocols and in commercial product testing.

Other topics covered included educational needs, the use of bioremediation in tandem with other technologies, pollution prevention, the status of regulations relevant to bioremediation, an update on the Bioremediation Field Initiative, and new directions for the BAC.

To receive a summary of the meeting, contact Tom Baugh at 202-260-7448; by telefax at 202-260-3861; or by mail at U.S. EPA, RD-681, 401 M Street SW., Washington, DC 20460.

ERL, Gulf Breeze, and EPRI Study Bioremediation at Mercury-Contaminated Sites

(Continued from page 2)

Treatments found to reduce the size of the CH_3Hg pool in microcosm experiments will then be applied to field enclosures to see if the results can be replicated in field conditions. If possible, caged fish will be placed in the enclosures to test if reduction in CH_3Hg concentration in the water results in a corresponding decrease of mercury accumulation by fish.

The most promising remedial strategy or strategies, based on stimulation of CH_3Hg degradation and Hg(II) reduction and subsequent volatilization, will be tested in a contaminated freshwater pond (Reality Lake, Oak Ridge, Tennessee). The proposed research should allow us to assess the use of microbes to manage the speciation of mercury, and thereby the bioaccumulation of CH_3Hg. Integrating the results of this study into an EPRI biogeochemical model also will allow a better understanding of mercury dynamics in a variety of mercury-impacted ecosystems such as the Florida Everglades, Onondaga Lake, and temperate lakes in the north central United States and Scandinavia.

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Abstract: 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; 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.