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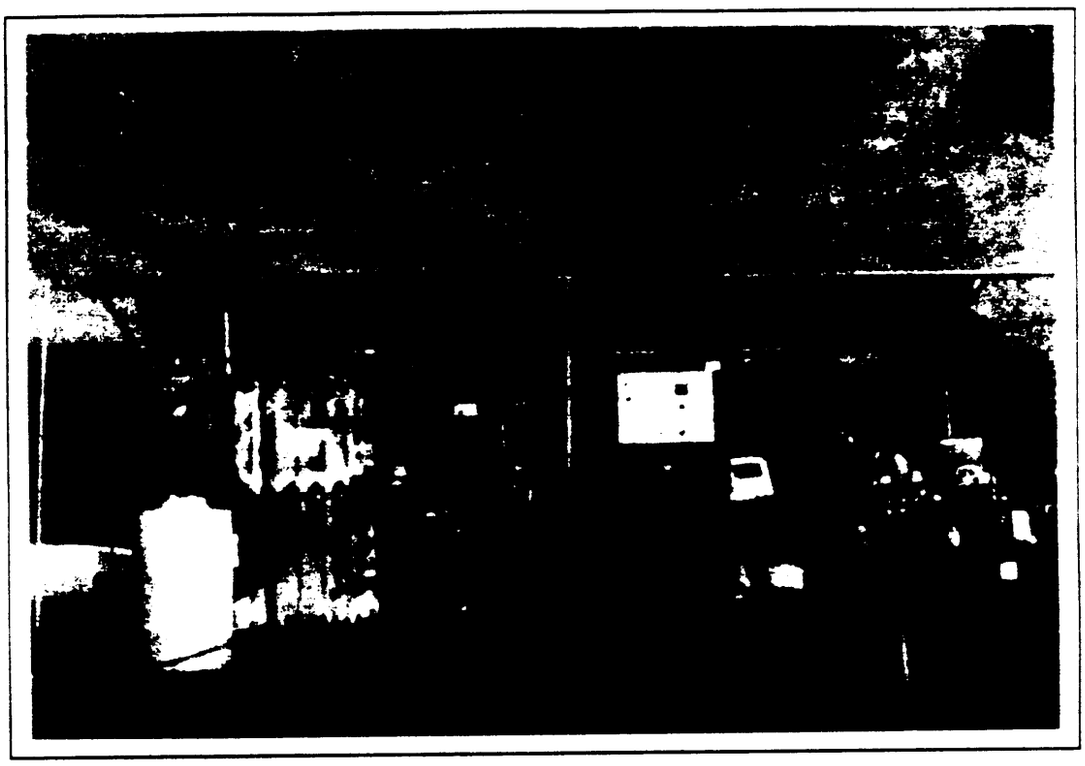
EPA Ground-Water Treatment Technology Resource Guide



- Abstracts of Policy, Guidance, and Technical Assistance Documents
- Summary of Regulatory Mechanisms that Affect Ground-Water Treatment Technologies
- Descriptions of Ground-Water Treatment Technology-Related Databases, Hotlines, Catalogs/Bibliographies, and Dockets
- Easy-to-Use Matrix that Assists in Identification of Appropriate Documents

NOTICE

This document was prepared by the United States Environmental Protection Agency under EPA Contract Number 68-W2-0004, Option 2, Subcontract No. 92-001-01. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

This document represents a series of technology resource guides prepared by the Technology Innovation Office. These include the following technology guides: the Bioremediation Resource Guide (EPA/542/B-93/004); the Physical/Chemical Treatment Technology Resource Guide (EPA/542/B-94/008); and the Soil Vapor Extraction Treatment Technology Resource Guide (EPA/542/B-94/007).

Information is included in this document on how to obtain these additional resource guides.

FOREWORD

Identifying and accessing pertinent information resource tools that will help site cleanup managers evaluate innovative technologies is key to the broader use of these technologies. This Guide is intended to increase awareness about technical information and specialized support services/resources related to ground water treatment technologies.

Specifically, this document identifies a cross section of information intended to aid users in remedial decision-making, including: abstracts of field reports and guidance documents; computer systems/data bases; pertinent regulations and associated guidance documents; program hotlines; as well as Federal centers for ordering publications. In addition, the look-up format of this document allows the user to quickly scan available resources and access more detailed abstracts, as desired.

Please let us know about additional information that could make this Guide (and others in the series) more useful to you.

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

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EXECUTIVE SUMMARY

This **Ground-Water Treatment Technology Resource Guide** is intended to support decision-making by Regional and State Corrective Action permit writers, Remedial Project Managers (RPMs), On-Scene Coordinators, contractors, and others responsible for the evaluation of technologies. This Guide directs managers of sites being cleaned up under the RCRA, UST, and CERCLA waste programs to ground-water treatment technology resource documents, databases, hotlines, and dockets and identifies regulatory mechanisms (e.g., Research Development and Demonstration Permits) that have the potential to ease the implementation of ground-water treatment at hazardous waste sites.

This Guide provides abstracts of representative examples of over 50 ground-water treatment technology guidance/workshop reports, overview documents, studies and demonstrations, and other resource guides. The **Ground-Water Treatment Technology Resource Matrix**, which accompanies this Guide, identifies the in situ treatment technology and contaminants covered in each abstracted document. Information contained in this Guide is not intended to be all-inclusive, nor does the inclusion of information represent an endorsement by the U.S. Environmental Protection Agency (EPA).

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INTRODUCTION

EPA is committed to identifying the most effective and efficient means of addressing the thousands of hazardous waste sites in the United States. Therefore, the Office of Solid Waste and Emergency Response's (OSWER's) Technology Innovation Office (TIO) at EPA is working in conjunction with the EPA Regions and research centers and industry to identify and further the implementation of innovative treatment technologies.

The goal of OSWER is to encourage the development and use of innovative hazardous waste treatment technologies. One way of enhancing the use of these technologies is to ensure that decision-makers can avail themselves of the most current information on technologies, policies, and other sources of assistance. This Guide was prepared to help identify documents that can directly assist RPMs and permit-writers in investigating existing information on ground-water treatment technologies applications for contaminants usually found at RCRA, UST, and CERCLA sites.

HOW TO USE THIS GUIDE

When using this Guide to identify resource information on ground-water treatment technologies, you may wish to take the following steps:

1. Turn to the **Ground-Water Treatment Technology Resource Matrix** located in the back of this Guide. This matrix lists alphabetically by document type over 60 ground-water treatment-related documents and identifies the type of information provided by each document, as well as a document ordering number.

2. Select the document(s) that appear to fit your needs based on the content information in the matrix.

3. Check the abstract identification code. This number refers to an abstract of the document. The number corresponds to a page number in the Guide and the letter corresponds to an abstract on that page. For example:

Abstract Identification Code :	**8**	**A** —	Abstract A on page 8 of the Resource Guide
	page 8 in the Resource Guide		

4. Review the abstract that corresponds to the document in which you are interested to confirm that the document will fit your needs.

5. If the document appears to be appropriate, check the document number highlighted under the abstract. For example:

EPA Document Number: EPA/540/S-92/003

6. Turn to the section entitled "How to Order Documents Listed in this Guide" on page 3 of this Guide and order your document using the directions listed. You will find order forms identified in the section entitled "Order Forms," which begins on page 29 of this Guide.

7. When seeking information on technical assistance sources, turn to page 4 of this Guide.

8. To identify information on Federal regulations and guidance relevant to ground water treatment technologies, turn to page 7 of this Guide.

9. If you would like to comment on this Guide or would like additional information, turn to page 27 of this Guide and follow the directions for mailing or faxing your comments/questions.

HOW TO ORDER DOCUMENTS LISTED IN THIS GUIDE

Documents listed in this Guide are available through a variety of sources. When ordering documents listed in the "Ground-Water Treatment Technology Abstracts" section of this Guide, use the number listed in the bar below the abstract. If using the **Ground-Water Treatment Technology Resource Matrix** in the back of the Guide, use the number listed below the document title. If multiple document ordering numbers are identified, select the appropriate number based on the directions below. EPA/530, EPA/540, EPA/600, and EPA/625 documents may be available through the Center for Environmental Research Information (CERI); EPA/540 and EPA/542 documents may be obtained through the National Center for Environmental Publications and Information (NCEPI); and EPA/530 may be obtained through the RCRA Information Center (RIC). These document repositories provide in-stock documents free of charge, but document supplies may be limited. Documents obtained through the National Technical Information Service (NTIS) are available for a fee; therefore, prior to purchasing a document through NTIS, you may also wish to review a copy at a technical or university library, or a public library that houses government documents.

Document Type	Document Source
Publication numbers with the following prefixes: AD DE PB PR (free of charge)	NTIS 5285 Port Royal Road Springfield, VA 22161 (703) 487-4650 fax requests to (703) 321-8547 8:30 a.m. - 5 p.m., Eastern Time.

NTIS provides documents for a fee. The "NTIS Order Form," included in the "Order Forms" section of this Guide, can be used to order from NTIS.

Publications with the following numbers: EPA/530 (limited collection) EPA/540 (limited collection) EPA/600 EPA/625	Center for Environmental Research Information (CERI) Cincinnati, OH 45268 (513) 569-7562 8:30 a.m. - 4:30 p.m., Eastern Time.

Out of stock documents may be ordered from NCEPI or may be purchased from NTIS.

Publications with the following numbers: EPA/540 EPA/542	National Center for Environmental Publications and Information (NCEPI) 11029 Kenwood Road, Building 5 Cincinnati, OH 45242 (513) 891-6561 fax requests to (513) 891-6685 8 a.m. - 5 p.m., Eastern Time.

A document title or number is needed to place an order with NCEPI. Some out of stock documents may be ordered from CERI or may be purchased from NTIS.

Publications with EPA/530 numbers	RCRA Information Center (RIC) 401 M St., S.W. Mailcode: 5305 Washington, DC 20460 (202) 260-9327 9 a.m. - 4 p.m., Eastern Time.

"Office of Solid Waste Publications Order Form," included in the "Order Forms" section of this Guide can be used to order from the RIC.

If you have difficulty finding a document or wish to obtain EPA/510 documents, call:
RCRA/Superfund/OUST Hotline ..... 800-424-9346, 703-412-9810, TDD: 800-553-7672, 703-412-3323

Operates Monday-Friday, 8:30 a.m. - 7:30 p.m., Eastern Time.
Hotline staff can help EPA staff or members of the public locate documents and assist callers with placing document orders.

SOURCES OF GROUND-WATER TREATMENT TECHNOLOGY INFORMATION/TECHNICAL ASSISTANCE

Numerous computer-based bulletin boards, regulatory hotlines, dockets, databases, catalogs/bibliographies, and periodicals are also available. These resources provide technical information on ground-water treatment technology and other innovative technologies and guide you to additional valuable resources. Most bulletin board services are provided free of charge.

BULLETIN BOARDS:

- **Alternative Treatment Technologies Information Center (ATTIC) data line .. 703-908-2137**
  Users can access this collection of hazardous waste databases through a bulletin board. Provides hazardous waste abstracts, news bulletins, conference information, and a message board.

  Help Line 703-908-2138
  Provides information on access to ATTIC.

- **Cleanup Information Bulletin (CLU-IN) data line 301-589-8366**
  Provides hazardous waste professionals with current information on innovative technologies via a bulletin board. Provides information bulletins, message and on-file exchange, and on-line databases and directories.

  Help Line 301-589-8368
  Addresses questions about CLU-IN access and contents; addresses problems with the service.

- **Office of Research and Development (ORD)**
  Data line 800-258-9605
  Bulletin Board Service (BBS)
  Data line 513-569-7610
  Provides a bibliography of over 19,000 documents and a message board.

  Help Line 513-569-7272
  Provides information on access to and contents of the ORD BBS.

CATALOGS/BIBLIOGRAPHIES/DIRECTORIES:

- **Accessing Federal Data Bases for Contaminated Site Clean-Up Technologies, Third Edition, September 1993**
  EPA/542/B-93/008
  Provides information on those systems maintaining data on remedial technologies, including information on data elements, system uses, hardware and software requirements, and access.

- **Catalog of Hazardous and Solid Waste Publications, Sixth Edition** EPA/530-B-92-001
  Catalogs Office of Solid Waste policy directives, guidance documents, brochures, Regulatory Development Branch memos, and other documents relevant to hazardous and solid waste.

- **Compendium of Superfund Program Publications**
  EPA/540/8-91/014, NTIS PR 881
  Provides abstracts and ordering information for fact sheets, directives, publications, and computer materials on Superfund. Use the document ordering directions to obtain the Compendium.

- **Federal Publications on Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation, Third Edition, September 1993**
  EPA/542/B-93/007
  Lists Federal publications on innovative treatment technologies, including thermal, biological, and physical/chemical processes; technology survey reports; treatability studies; and reports on ground water and community relations.

- **Ground-Water Research, Technical Assistance Directory, Third Edition** EPA/600/9-91/006
  Lists research contacts in EPA Headquarters and Regional offices. In addition, the directory provides brief organizational descriptions of the ground-water research program for each ORD office.

- **Literature Review of Nonbiological Remediation Technologies Which May Be Applicable to Fertilizer/ Agrichemical Dealer Sites**
  NTIS DE93003877/XAB
  This bulletin provides a general literature overview of the more prominent nonbiological remediation technologies that may be applicable to fertilizer/agrichemical dealer sites.

- **Literature Survey of Innovative Technologies for Hazardous Waste Site Remediation, 1987-1991**
  EPA/542/B-92/004, NTIS PB93-105617
  Provides a survey of publications useful to those investigating innovative technologies. Includes information on current developments and identifies references to support additional research.

- **Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation, November 1993 Update**
  EPA/542/B-93/010
  Provides a list of EPA information resources related to the use of alternative and innovative treatment technologies, including guidance documents, study results, bulletins, and databases.

- **Technical Assistance Directory, July 1993**
  EPA/600/K-93/006
  Lists the programs, areas of expertise, and primary contacts in each of the major Office of Research and Development (ORD) operations.

DATABASES/SOFTWARE:

- **DIALOG Database 800-3-DIALOG**
  Contains files relevant to hazardous waste including: Enviroline, CA Search, Pollution Abstracts, Compendex, Energy Science and Technology, National Technical Information Service (NTIS), and others.

  NTIS Database
  Contains abstracts of government-sponsored research, development, and engineering analyses prepared by approximately 250 Federal agencies and some State and local governments. Accessible via the DIALOG system.

SOURCES OF GROUND-WATER TREATMENT TECHNOLOGY INFORMATION/TECHNICAL ASSISTANCE (CONT'D)

- **Exposure Models Library and Integrated Model Evaluation**
  EPA/600/C-92/002
  Presents about 90 exposure models for determining fate and transport in various environmental media.

- **FEDWORLD**
  To access via modem 703-321-8020
  To access via Internet ..... telnet fedworld.gov or 192.239.92.201
  Allows access to more than 100 Federally-operated on-line computer systems, including eight environmentally related systems, under a single umbrella. Environmental systems include the Alternative Treatment Technology Information Center, the Waste Water Treatment Information Exchange, the CLU-IN (Superfund) Bulletin Board, the Clean-Up Standards and Outreach Bulletin Board, the Office of Research and Development Bulletin Board, and the Pesticide Information Network. FEDWORLD operates 24 hours a day, seven days a week, free of charge.

  Help Line 703-487-4608
  Answers questions about access and contents.

- **Records of Decision System (RODs)**
  To get information on accessing RODs 703-271-5400
  Contains the full text of all signed RODs for hazardous waste clean-up sites nationwide. Direct access to RODS is available to EPA personnel and organizations that have relevant EPA contracts. Regional libraries will provide public citizens with ROD information.

- **Risk Reduction Engineering Laboratory Treatability Database**
  To fax a request 513-891-6685
  To send a request NCEPI
  P.O. Box 42419
  Cincinnati, OH 45242-2419
  Contains extensive review of the removal and destruction of 1,200 chemicals in both aqueous and solid media. Send a fax to the above number or mail a request to the above address to order, free of charge, the database on 3 1/2" disk.

- **Vendor Information System for Innovative Treatment Technologies (VISITT) 800-245-4505**
  Contains current information on the availability, performance, and cost of innovative technologies to remediate hazardous waste sites.

DOCKETS:

- **Federal Facilities Docket Hotline 800-548-1016**
  Provides the name, address, NPL status, agency, and Region for the Federal facilities listed on the Federal Facilities Docket. Facilities are on the docket because they reported being a RCRA TSDF or having spilled or having the potential to release CERCLA hazardous waste. Operates Monday - Friday, 8:30 a.m. - 5:30 p.m., Eastern Time.

- **OUST Docket 202-260-9720**
  Provides documents and regulatory information pertinent to *RCRA Subtitle I (the Underground Storage Tank program). Operates Monday - Friday, 9 a.m. - 4:30 p.m., Eastern Time.*

- **RCRA Information Center 202-260-9327**
  Indexes and provides public access to all regulatory materials supporting the Agency's actions under RCRA, and disseminates current Office of Solid Waste publications. Operates Monday - Friday, 9 a.m. - 4 p.m., Eastern Time.

- **Superfund Docket 202-260-3046**
  Provides access to Superfund regulatory documents, Superfund Federal Register Notices, and RODs. Operates Monday - Friday, 9 a.m. - 4 p.m., Eastern Time.

HOTLINES/REGULATORY/TECHNICAL ASSISTANCE:

- **Ground-Water and Drinking-Water Resource Center 202-260-7786**
  Distributes ground-water and drinking-water publications and maintains a bibliographic database on Office of Ground-Water and Drinking-Water documents. Operates Monday - Friday, 8:30 a.m. - 5 p.m., Eastern Time.

- **Ground-Water Fate and Transport Technology Support Center 405-436-8603**
  Provides technical support on general ground-water remediation technologies and provides a catalog of various ground-water remediation technologies. Operates Monday - Friday, 8 a.m. - 4 p.m., Central Time.

- **RCRA/Superfund/OUST Hotline ..... 800-424-9346, 703-412-9810, TDD: 800-553-7672, 703-412-3323**
  Provides regulatory assistance related to RCRA, CERCLA, and UST programs. Serves as a liaison between the regulated community and EPA personnel and provides information on the availability of relevant documents. Operates Monday - Friday, 8:30 a.m. - 7:30 p.m., Eastern Time.

- **Superfund Health Risk Technical Support Center 513-569-7300**
  Provides EPA Regional Superfund risk assessors, State agencies, and those working under EPA contract with technical, typically chemical-specific, support and risk assessment review. Operates Monday - Friday 8 a.m. - 5 p.m., Eastern Time.

- **TSCA Hotline 202-554-1404**
  Answers public and private regulatory questions on TSCA. Refers callers to appropriate EPA contacts, and takes TSCA-relevant document orders. Operates Monday - Friday, 8:30 a.m. - 5 p.m., Eastern Time.

INFORMATION CENTER:

- **National Center for Environmental Publications and Information (NCEPI) 513-891-6561**
  To fax a request 513-891-6685
  Stores and distributes to public and private callers a limited supply of most EPA publications, videos, posters,

and other multi-media materials. Callers should know document titles or numbers when calling. The following documents can be obtained from NCEPI, while supplies last.

Bioremediation in the Field
A periodical devoted to bioremediation that contains 140 potential applications of bioremediation, including bioremediation for remedy of contaminated ground water.

Ground Water Currents
A newsletter that reports on innovative in situ and ex situ ground-water remediation technologies to be applied in the field.

LIBRARIES:

- The EPA Headquarters and Regional Libraries provide information services covering a wide range of environmental and related subjects, including hazardous waste, air and water pollution and control, environmental law, solid waste, toxic substances, and test methods. These libraries also provide a collection of materials on social, economic, legislative, legal, administrative, and management projects related to all aspects of environmental policy. EPA Headquarters and Regional Libraries contact information is provided below. In addition to resources available through EPA libraries, users may also access relevant documents through university libraries or other public libraries that house government documents.

  - **EPA Headquarters Library 202-260-5921**
    Operates Monday - Friday, 10a.m. - 2p.m., Eastern Time

  - **Region 1 Library (Boston, MA) 617-565-3300**
    Fax 617-565-3346
    Operates Monday - Friday, 8:30a.m. - 5p.m., Eastern Time

  - **Region 2 Library (New York, NY) 212-264-2881**
    Fax 212-264-5433
    Operates Monday - Friday (except Tuesday), 8:30a.m. - 5p.m., Eastern Time
    Operates Tuesday, 1p.m. - 5p.m., Eastern Time

  - **Region 3 Library (Philadelphia, PA) 215-597-0580**
    Fax 215-597-7906
    Operates Monday - Friday, 8a.m. - 4p.m., Eastern Time

  - **Region 4 Library (Atlanta, GA) 404-347-4216**
    Fax 404-347-4486
    Operates Monday - Friday, 8a.m. - 3:45p.m., Eastern Time

  - **Region 5 Library (Chicago, IL) 312-353-2022**
    Fax 312-353-1155
    Operates Monday - Friday, 7:30a.m. - 5p.m., Central Time

  - **Region 6 Library (Dallas, TX) 214-665-6427**
    Fax 214-665-2146
    Operates Monday - Friday, 7:30a.m. - 4:30p.m., Central Time

  - **Region 7 Library (Kansas City, KS) 913-551-7358**
    Fax 913-551-7467
    Operates Monday - Friday, 9a.m. - 5:30p.m., Central Time

  - **Region 8 Library (Denver, CO) 303-293-1444**
    Fax 303-294-1087
    Public Information Center Operates Monday - Friday 8a.m. - 5p.m., Library Operates Monday - Friday, 12p.m. - 4p.m., Mountain Time

  - **Region 9 Library**
    (San Francisco, CA) 415-744-1510
    Fax 415-744-1474
    Operates Monday - Friday, 9a.m. - 5p.m., Western Time

  - **Region 10 Library**
    (Seattle, WA) ..... 206-553-1289 or 1259
    Fax 206-553-8509
    Operates Monday - Friday, 9a.m. - 4p.m., Western Time

- **RREL/Site Superfund Videotape**
  Library 201-535-2219
  Provides composite videotapes containing a number of EPA-produced documentaries on specific Superfund Innovative Technology Evaluation (SITE) Program demonstrations. Operates Monday - Friday, 8:30a.m. - 4:30p.m., Eastern Time

FEDERAL REGULATIONS AND GUIDANCE RELEVANT TO GROUND WATER TREATMENT TECHNOLOGIES

This table lists pertinent RCRA regulations, with the *Code of Federal Regulations (CFR)* and *Federal Register (FR)* citations and provides information on guidance documents relevant to these regulations. In addition, States may elect to have more stringent regulations than the Federal regulations identified here. Contact your State environmental protection agency when considering the applicability of any of the following Federal regulations.

CITATION	REGULATION	DESCRIPTION	GUIDANCE
40 *CFR* Part 261 February 18, 1994 59 *FR* 8362	**Treatability Study Exemption**	Provides for treatability studies under RCRA	Conducting Treatability Studies Under RCRA (7/92, OSWER Directive 9380.3-09FS, NTIS PB92-963-501)
40 *CFR* §270.65 July 15, 1985 50 *FR* 28728	**Research Development and Demonstration Permits**	Allows the issuance of a RCRA permit for a pilot scale study pertaining to an innovative or experimental technology	Guidance Manual for Research Development and Demonstration Permits (7/86, EPA/530-SW-86-008, OSWER Directive 9527.00-1A, NTIS PB86-229192/AS)
40 *CFR* §270.42(e) December 10, 1987 52 *FR* 46946	**Subpart X Miscellaneous Units**	Allows the issuance of a RCRA permit for a miscellaneous unit	*No guidance specifically related to ground-water technologies is available.*
40 *CFR* §270.42(e) March 7, 1989 54 *FR* 9596 (Changes certain permit modifications for hazardous waste)	**RCRA Permit Modification Rule: Temporary Authorization**	Allows the permitting agency to grant a facility a temporary authorization to perform certain activities (e.g., cleanups, corrective action, and closure activities) for up to 180 days	Modifying RCRA Permits (9/89, EPA/530-SW-89-050)
40 *CFR* §268.40 June 1, 1990 55 *FR* 22686 (Presents third-third wastes)	**Land Disposal Restrictions (LDR) Subpart D - Treatment Standards**	Sets forth RCRA hazardous waste treatment standards	Land Disposal Restrictions Summary of Requirements (2/91, OSWER Directive 9934.0-1A, NTIS PB91-190835)
40 *CFR* §268.44(h) August 17, 1988 53 *FR* 31143, 31185, 31188, 31196, 31199, 31202 (Presents final rule on first-third wastes and national capacity variances)	**Variance from an LDR Treatment Standard**	Allows for a site-specific treatability variance to be issued as a nonrulemaking procedure	Regional Guide: Issuing Site-Specific Treatability Variances for Contaminated Soils and Debris from LDRs (1/92, OSWER Directive 9380.3-08FS, NTIS PB92-963284) No Migration Variances to the Hazardous Waste Land Disposal Prohibitions: A Guidance Manual for Petitioners (7/92, NTIS PB92-207695)
40 *CFR* §264.552 February 16, 1993 58 *FR* 8658	**Corrective Action Management Unit (CAMU)**	Encourages treatment, including use of innovative treatment, instead of containment	Environmental Fact Sheet: EPA Issues Final Rules for Corrective Action Management Units and Temporary Units (1/93, EPA/530-F-93-001)
40 *CFR* §264.1030 June 21, 1990 55 *FR* 25454	**Air Emission Standards for Process Vents**	Sets forth standards for process vents associated with RCRA permitted hazardous waste facilities that manage waste with organic concentrations of at least 10 ppm	Hazardous Waste TSDF - Technical Guidance Document for RCRA Air Emission Standards for Process Vents and Equipment Leaks (7/90, EPA/450-3-89-021, NTIS PB90-263880)
40 *CFR* §264.1050 June 21, 1990 55 *FR* 25454	**Air Emission Standards for Equipment Leaks**	Sets forth standards for process vents associated with RCRA permitted hazardous waste facilities that manage waste with organic concentrations of at least 10% by weight	Hazardous Waste TSDF - Technical Guidance Document for RCRA Air Emission Standards for Process Vents and Equipment Leaks (7/90, EPA/450-3-89-021, NTIS PB90-263880)
40 *CFR* §264.90 July 26, 1982 47 *FR* 32274	**Ground Water Monitoring**	Sets forth ground water monitoring regulations for RCRA permitted treatment, storage, and disposal facilities	RCRA Ground-Water Monitoring: Draft Technical Guidance (11/92, EPA/530-R-93-001, NTIS PB93-139350) Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities; Draft Addendum to Interim Final Guidance (EPA/530/R-93/003, PB89-151047) Handbook of RCRA Ground-Water Monitoring Constituents: Chemical and Physical Properties (40 CFR Part 264, Appendix IX, June 1992) (EPA/530/R-92/002, PB92-233287) GRITS/STAT - A ground water information system tracking system with statistical analysis capability (EPA/625/11-91/002)

GRoundwater Information **T**racking **S**ystem with **STAT**istical Analysis Capability (**GRITS/STAT**) is a comprehensive ground-water database system designed to store, analyze, and report data generated from ground water monitoring programs such as facilities regulated by RCRA Subtitles C & D. GRITS/STAT is IBM PC/AT compatible, includes a User's Manual, and is available as an EPA ORD Publication (EPA 625/11-91/002). For more information contact Jack Teuschler at EPA/ORD/RREL (513) 567-7314.

ABSTRACTS OF GROUND-WATER TREATMENT TECHNOLOGY RESOURCES

The following abstracts describe the contents of pertinent ground-water treatment technology documents, which are organized alphabetically within each document type. Documents that address the same site are grouped together and listed in alphabetical order by site name. Document types included are:

Begins on Page

- Guidance/Workshops 8
- Overview Documents 8
- Studies and Demonstrations 14
- Other Resource Guides 25

To quickly identify documents pertinent to your interest area, see the **Ground-Water Treatment Technology Resource Matrix** in the back of this Guide. The documents in the matrix are categorized using the document types identified above and can be cross-referenced with the abstracts using the code to the left of the document titles on the matrix. In an effort to limit the number of resources listed here, Records of Decision (RODs), documents more than five years old, and most proceedings are not included. Those seeking RODs or proceedings may wish to contact the hotlines, dockets, etc. listed on page 4 of this Guide. These abstracts were pulled from the NTIS Database.

GUIDANCE/WORKSHOPS

8A

Biotechnology Workgroup for Department of Defense Soil and Ground Water Decontamination Applications, Final Report for Period Ending March 1989.
Reuter, R. H., Life Systems, Inc., Cleveland, OH, Naval Civil Engineering Laboratory, Port Hueneme, CA, June 1991

NTIS Document Number: AD-A237 956/8/XAB

This report contains materials used in and generated by the Department of Defense Biotechnology Workshop on Soil and Ground-Water Decontamination Applications. Various bioremediation techniques for treating soil and water contaminated with sludges, solvents, toxins, acids, bases, and heavy metals were discussed as well as the overall place of biotechnology in Installation Restoration programs. Among the specific applications discussed were: biochemical sensors to determine environmental stress in organisms; in situ detoxification and biodecontamination of pollutants in soils and waste streams; sequestration, removal, and recovery of metals in waste streams with metal-binding proteins; and the use of vegetation to limit the transport to sequester and/or to remove contaminants from soil or water.

8B

NPL Construction Completion Definition at Bioremediation and Soil Vapor Extraction Sites Directive.
U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC, June 1993

EPA Document Number: EPA/540/F-93/019

NTIS Document Number: PB93-963327/XAB

The report discusses EPA's policy for categorizing bioremediation and soil vapor extraction sites as Construction Completions. Technologies addressed are: in situ soil vapor extraction, in situ bioremediation, and ex situ bioremediation.

OVERVIEW DOCUMENTS

8C

An Overview of Underground Storage Tank Remediation Options.
U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC, October 1993

EPA Document Number: EPA/510/F-93/029

This document contains a series of fact sheets to answer basic questions about selected alternative cleanup technologies and to provide an easy way to compare one another. The ground-water remediation technologies include: in situ air sparging with soil vapor extraction, in situ bioremediation, in situ bioventing combined with low flow air sparging (biosparging), and vacuum enhanced pump and treat.

8D

Bioremediation.
Thomas, J. M.; Ward, C. H.; Raymond, R. L.; Wilson, J. T.; and Loehr, R. C., U.S. Environmental Protection Agency, RobertS. Kerr Environmental Research Laboratory, Ada,

OK, National Center for Ground Water Research, Houston, TX, 1992

EPA Document Number: EPA/600/A-93/004

NTIS Document Number: PB93-149193/XAB

Bioremediation is defined in the article as the process by which microorganisms are stimulated to rapidly degrade hazardous organic contaminants to environmentally safe levels in soils, subsurface materials, water, sludges, and residues. Stimulation is achieved by the addition of nutrients and a terminal electron acceptor, usually oxygen, because most biological reactions occur faster under aerobic than anaerobic conditions. Under anaerobic conditions, nitrate has been used as the terminal electron acceptor. The microorganisms use the contaminants as a food source and convert the contaminants into biomass and harmless by-products of metabolism such as CO_2 and inorganic salts. Usually bioremediation is used to degrade contaminants that are sorbed to surfaces or dissolved in water rather than to degrade pure chemicals. As a result, the process is used in conjunction with other techniques in remediation of contaminated sites. The contaminants can be biodegraded in situ or removed and placed in a bioreactor, which can be placed off or at the site where the contamination occurred.

9A

Critical Review of In Situ Bioremediation, Topical Report, January 1990-March 1992.
Rittmann, B. E.; Valocchi, A. J.; Seagren, E.; Ray, C.; and Wrenn, B., Illinois University at Urbana-Champaign, Newmark Civil Engineering Laboratory, North Dakota University, Grand Forks, ND; Energy and Environmental Research Center, Gas Research Institute, Chicago, IL; U.S. Department of Energy, Morgantown Energy Technology Center, Morgantown, WV, August 1992

NTIS Document Number: PB93-114247/XAB

In situ bioremediation, which is the managed, in-place cleanup of contaminated ground water aquifers and surface soils by microorganisms, is a promising technology because it is versatile and can have significant economic advantages. Many common contaminants are biodegradable, and new microbial capabilities for degradation are being discovered all the time. Success in the field and in laboratory studies point out the promise. On the other hand, the promises are not yet fulfilled, mainly because of the complexity of the subsurface situation. The report provides a comprehensive and in-depth critical review of in situ bioremediation. It is organized to evaluate the possibilities and restrictions inherent in all facets of in situ bioremediation, including microbiology, hydrodynamics, engineering, and legal and other nontechnical aspects. Several of the key conclusions are illustrated by case studies of successful field projects. Finally, the research needed to advance in situ bioremediation to become a reliable and acceptable tool is outlined.

9B

Evaluation of Ground-Water Extraction Remedies: Phase 2, Volume 1, Summary Report.
U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, February 1992

NTIS Document Number: PB92-963346/XAB

The report is the second phase of a study to evaluate the effectiveness of ground-water extraction systems being used to remediate ground-water contamination at hazardous waste sites. The report was prepared in two volumes. Volume 1 contains an executive summary and chapters which discuss the purpose, methodologies, and conclusions of the project.

9C

Fifth Forum on Innovative Hazardous Waste Treatment Technologies: Domestic and International, Proceedings, Chicago, Illinois, May 3-5, 1994.
U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Technology Innovation Office, Office of Research and Development, Washington, DC, Risk Reduction Engineering Laboratory, Cincinnati, OH, May 1994

EPA Document Number: EPA/540/R-94/503

On May 3-5, 1994, the U.S. Environmental Protection Agency's Technology Innovation Office and Risk Reduction Engineering Laboratory hosted an international conference in Chicago, Illinois to exchange solutions to hazardous waste treatment problems. During the conference, scientists and engineers representing government agencies, industry, and academia attended over 40 technical presentations and case studies describing domestic and international technologies for the treatment of waste, sludges, and contaminated soils at uncontrolled hazardous waste disposal sites. A session was also held on opportunities in research and commercialization, which included presentations on export assistance programs and partnerships with EPA in developing innovative technologies. This compendium includes the abstracts of the presentations from the conference and many of the posters that were on display.

9D

Fourth Forum on Innovative Hazardous Waste Treatment Technologies: Domestic and International, Technical Papers, San Francisco, California, November 17-19, 1992.

U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Technology Innovation Office, Office of Research and Development, Washington, DC, Risk Reduction Engineering Laboratory, Cincinnati, OH, February 1993

EPA Document Number: EPA/540/R-93/500

On November 17-19, 1992, the U.S. Environmental Protection Agency's Technology Innovation Office and Risk Reduction Engineering Laboratory, the Department of Energy, the Corps of Engineers, and the California Environmental Protection Agency, hosted an international conference in San Francisco, California, to exchange solutions to hazardous waste treatment problems. This conference was attended by approximately 1,000 representatives from the U.S. and 25 foreign countries. During the conference, scientists and engineers representing government agencies, industry, and academia attended 42 technical presentations and case studies describing domestic and international technologies for the treatment of waste, sludges, and contaminated soils at uncontrolled hazardous waste disposal sites. Technologies included physical/chemical, biological, thermal, and stabilization techniques. Presentations were made by EPA, their Superfund Innovative Technology Evaluation (SITE) program participants, other Federal and State agencies and their contractors, international scientists, and vendors. This document contains abstracts of the presentations from the conference and many of the posters that were on display.

10A

Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration.
U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC, September 1993

EPA Document Number: EPA/540/R-93/080

NTIS Document Number: PB93-963507/XAB

This guidance clarifies how EPA will determine whether ground water restoration is technically impracticable and what alternative measures or action must be undertaken to ensure that the final remedy is protective of human health and the environment. Topics covered include the types of technical data and analyses needed to support EPA's evaluation of a particular site and the criteria used to make a determination. As technical impracticability (TI) decisions are part of the process of site investigation, remedy selection, remedial action, and evaluation of remedy performance, the guidance also briefly discusses the overall framework for decision making during these phases of site cleanup.

10B

Innovative Treatment Technologies: Annual Status Report, Fifth Edition.
Fiedler, L., U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Technology Innovation Office, Washington, DC, September 1993

EPA Document Number: EPA/542/R-93/003

NTIS Document Number: PB93-133387/XAB

This annual report contains site-specific information on Superfund sites (both remedial and emergency response actions) and non-Superfund sites (within the Departments of Defense and Energy) where innovative treatment technologies have been or are being used. Innovative treatment technologies are treatment technologies for which a lack of data on cost and performance makes their selection and use at Superfund sites more difficult. The report documents the use of the following innovative treatment technologies to treat ground water in situ; soils, sediments, sludge, and solid-matrix wastes; bioremediation (ex situ); bioremediation (in situ); chemical treatment; dechlorination; in situ flushing; in situ vitrification; soil vapor extraction; soil washing; solvent extraction; thermal desorption; and other technologies.

10C

Innovative Treatment Technologies: Overview and Guide to Information Sources.
Quander, J. and Kingscott, J., U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Technology Innovation Office, Washington, DC, October 1991

EPA Document Number: EPA/540/9-91/002

NTIS Document Number: PB92-179001/XAB

The document is a compilation of information on innovative treatment technologies being used in the Superfund program and is intended to assist site project managers, consultants, responsible parties, and owner/operators in their efforts to identify current literature on innovative treatment technologies for hazardous waste remediation on corrective action. The technologies addressed in the guide include the following: incineration, thermal desorption, soil washing, solvent extraction, dechlorination, bioremediation, vacuum extraction, vitrification, and ground-water treatment. Also included in the guide for the user's reference are summary statistics of EPA's selection and application of innovative treatment technologies between 1982 and 1990. In addition, for each technology the

guide provides a detailed description, status of development and application, strengths, weaknesses, and materials handling considerations. A comprehensive bibliography for each technology can be found within each chapter.

11A

In Situ Bioremediation of Contaminated Ground Water.
Sims, J. L.; Suflita, J. M.; and Russell, H. H.; U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC, February 1992

EPA Document Number: EPA/540/S-92/003

NTIS Document Number: PB92-224336/XAB

In-situ bioremediation, where applicable, appears to be a potential cost-effective and environmentally acceptable remediation technology. Suflita (1989) identified characteristics of the ideal candidate site for successful implementation of in-situ bioremediation. These characteristics included: (1) a homogeneous and permeable aquifer; (2) a contaminant originating from a single source; (3) a low ground-water gradient; (4) no free product; (5) no soil contamination; and (6) an easily degraded, extracted, or immobilized contaminant. Obviously, few sites meet these characteristics. However, development of information concerning site-specific geological and microbiological characteristics of the aquifer, combined with knowledge concerning potential chemical, physical, and biochemical fate of the wastes present, can be used to develop a bioremediation strategy for a less-than-ideal site.

11B

In Situ Bioremediation of Ground Water and Geological Material: A Review of Technologies, Research Report.
Norris, R. D.; Hinchee, R. E.; Brown, R.; and McCarty, P. L.; Semprini, L.; Dynamac Corporation, Ada, OK, U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, OK, July 1993

EPA Document Number: EPA/600/R-93/124

NTIS Document Number: PB93-215564/XAB

The report provides the reader with a detailed background of the technologies available for the bioremediation of contaminated soil and ground water. The document has been prepared for scientists, consultants, regulatory personnel, and others who are associated in some way with the restoration of soil and ground water at hazardous waste sites. It provides the most recent scientific understanding of the processes involved with soil and ground-water remediation, as well as a definition of the state-of-the-art technologies with respect to circumstances of their applicability and their limitations. In addition to discussions and examples of developed technologies, the report also provides insights to emerging technologies that are at the research level of formation, ranging from theoretical concepts, through bench-scale inquiries, to limited field-scale investigations. The report centers around a number of bioremediation technologies applicable to the various subsurface compartments into which contaminants are distributed. The processes that drive these remediation technologies are discussed in depth along with the attributes that direct their applicability and limitations according to the phases into which the contaminants have partitioned. These discussions include in situ remediation systems, air sparging and bioventing, use of electron acceptors alternate to oxygen, natural bioremediation, and introduction of organisms into the subsurface. The contaminants of major focus in the report are petroleum hydrocarbons and chlorinated solvents.

11C

In Situ Bioremediation of Ground Water, Summary Paper.
U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, OK, January 1993

EPA Document Number: EPA/540/S-92/017

NTIS Document Number: PB93-146850/XAB

The Robert S. Kerr Environmental Research Laboratory (RSKERL) has developed a number of issue papers and briefing documents that are designed to exchange up-to-date information related to the remediation of contaminated soil and ground water at hazardous waste sites. In an attempt to make the content of these documents available to a wider audience, RSKERL is developing a series of summary papers that are condensed versions of the original documents. There are a number of techniques that may potentially be used for dealing with problems resulting from the contamination of ground water with organic compounds. Ground water can sometimes be treated in place using chemical or biological processes. An emerging technology for the in situ remediation of ground water is the use of microorganisms to degrade contaminants that are present in aquifer materials. Although in situ bioremediation has been used for a number of years in the restoration of ground water contaminated with petroleum hydrocarbons, its application to other classes of contaminants is relatively recent. This is discussed in the summary paper.

11D

In Situ Treatment of Contaminated Ground Water: An Inventory of Research and Field Demonstrations and Strategies for Improving Ground Water Remediation Technologies.
U.S. Environmental Protection Agency, Office of Solid

Waste and Emergency Response, Technology Innovation Office, Washington, DC, January 1993

EPA Document Number: EPA/500/K-93/001

NTIS Document Number: PB93-193720/XAB

The predominance of ground-water contamination at hazardous waste sites and the dearth of methods to efficiently treat this contamination is a problem that the U.S. Environmental Protection Agency (EPA) is examining. The contaminated ground water found at most Superfund sites is often the limiting factor for complete site remediation. The purpose of the document is to describe recent research, development, and application of technologies that either treat ground-water contaminants in place or improve the solubility and mobility of contaminants to enhance pump-and-treat remediation effectiveness. The report discusses techniques that can be applied in situ and excludes pumping methodologies or surface treatment systems. In addition, the publication presents conclusions based on observations of the survey. Finally, strategies for action for stakeholders concerned with in situ ground-water technology development are presented. The study has not defined the extent or activities of research and development outside of EPA-supported groups.

12A

Superfund Innovative Technology Evaluation (SITE) Program: Innovation Making a Difference.
U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, Cincinnati, OH, May 1994

EPA Document Number: EPA540/F-94/505

The SITE Program encourages commercialization of innovative technologies for characterizing and remediating hazardous waste site contamination through four components: demonstration; emerging technology; monitoring and measurement programs; and technology transfer activities. The information presented in this brochure addresses the demonstration segment of the program. The demonstration component evaluates promising innovative remedial technologies on site and provides reliable performance, cost, and applicability information for making cleanup decisions. This document lists the advantages of the SITE Program, as well as statistics such as the percentage of RODs using innovative technology, cost savings with innovative technologies for 17 sites, and market activities as reported by SITE vendors.

12B

Superfund Innovative Technology Evaluation Program: Technology Profiles, Sixth Edition.
U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, Cincinnati, OH, November 1993

EPA Document Number: EPA/540/R-93/526

NTIS Document Number: PB93-163053/XAB

This document contains a collection of abstracts describing innovative technologies being implemented in the Superfund Innovative Technology Evaluation Program for treating contaminated ground water, soils, and sludges. Each technology profile contains a: 1) technology description, 2) discussion of waste applicability, 3) schematic diagram or photograph of the process, and 4) summary of demonstration results. The document contains over 30 abstracts concerning ground-water remediation.

12C

Surfactants and Subsurface Remediation, Journal Article: Published in *Environmental Science Technology*, v26n12, pg. 2324-2330, 1992.
West, C. C. and Harwell, J. H., U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, OK, Oklahoma University Research Institute, OK, 1992

EPA Document Number: EPA/600/J-93/005

NTIS Document Number: PB93-149854/XAB

Because of the limitations of pump-and-treat technology, attention is now focused on the feasibility of surfactant use to increase its efficiency. Surfactants have been studied for use in soil washing and enhanced oil recovery. Although similarities exist between the applications, there are significant differences in the objectives of the technologies and the limitations placed on surfactant use. This article reviews environmental studies concerned with the fate and transport of surface-active compounds in the subsurface environment and discuss key issues related to their successful use for in situ aquifer remediation, particularly with respect to nonaqueous-phase liquids.

12D

Synopses of Federal Demonstrations of Innovative Site Remediation Technologies.
U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Technology Innovation Office, Washington, DC, Prepared by the Member Agencies of the Federal Remediation Technologies Roundtable, October 1993

EPA Document Number: EPA/542/B-93/009

NTIS Document Number: PB94-151065/XAB

This collection of abstracts describes demonstrations of innovative technologies to treat hazardous waste including remediation costs and contacts. The collection is intended to be an information resource for hazardous waste site project managers for assessing the availability and viability of innovative technologies for treating contaminated ground water, soils, and sludge. It is also intended to assist government agencies in coordinating ongoing hazardous waste remediation technology research initiatives, particularly those sponsored by the U.S. Environmental Protection Agency, U.S. Department of Energy, and U.S. Department of Defense. In total 75 demonstrations in seven different categories are described.

13A

TCE Removal from Contaminated Soil and Ground Water.
Russell, H.H.; Matthews, J.E.; and Sewell, G.W. Robert S. Kerr Environmental Laboratory, Ada, OK, U.S. Environmental Protection Agency, Office of Research and Development, Office of Solid Waste and Emergency Response, Technology Innovation Office, Washington, DC, January 1992

EPA Document Number: EPA/540/S-92/002

NTIS Document Number: PB92-224104/XAB

The purpose of this paper is to present a synopsis of physiochemical properties and reactive mechanisms of Trichloroethylene (TCE) and to delineate and discuss promising remediation technologies that have been proposed and/or demonstrated for restoring TCE-contaminated subsurface environmental media. The technologies discussed include air stripping, granular activated carbon adsorption, soil venting, in-well aeration, bioremediation of extracted ground waters/subsurface air streams, and in situ bioremediation.

13B

Technologies to Remediate Hazardous Waste Sites.
Falco, J.W., Battelle Pacific Northwest Laboratories, Richland, WA, March 1990

NTIS Document Number: DE90-011946/XAB

Technologies to remediate hazardous wastes must be matched with the properties of the hazardous materials to be treated, the environment in which the wastes are imbedded, and the desired extent of remediation. Many promising technologies are being developed and applied to remediate sites including biological treatment, immobilization techniques, and in situ methods. The management and disposal of hazardous wastes is changing because of Federal and State legislation, as well as public concern. Future waste management systems will emphasize the substitution of alternatives for the use of hazardous materials and process waste recycling. On site treatment will also become more frequently adopted.

13C

Technology Assessment of Soil Vapor Extraction and Air Sparging.
Loden, M. E.; Camp Dresser and McKee, Inc., Cambridge, MA, U.S. Environmental Protection Agency, Risk Reduction Engineering Laboratory, Cincinnati, OH, September 1992

EPA Document Number: EPA/600/R-92/173

NTIS Document Number: PB93-100154/XAB

Air sparging, also called "in situ air stripping" and "in situ volatilization," injects air into the saturated zone to strip away volatile organic compounds (VOCs) dissolved in ground water and adsorbed to soil. These volatile contaminants transfer in a vapor phase to the unsaturated zone where soil vapor extraction (SVE) can then capture and remove them. In addition to removing VOCs via mass transfer, the oxygen in the injected air enhances subsurface biodegradation of contaminants. Air sparging is a relatively new treatment technology. Research efforts have not yet fully elucidated the scientific basis (or limitations) of the system, nor completely defined the associated engineering aspects. However, a substantial body of available information describes the effectiveness and characteristics of air sparging systems. This document summarizes the available literature and addresses case studies of practical air sparging applications. It also identifies needs for further research.

13D

Technology Catalogue, First Edition.
Department of Energy, Office of Environmental Management, Office of Technology Development, Washington, DC, February 1994

DOE Document Number: DOE/EM-0138P

NTIS Document Number: DE94-008866/XAB

The catalogue provides performance data on the technologies developed by the Office of Technology Development (OTD) to scientists and engineers assessing and recommending technical solutions within the Department's clean-up and waste management programs, as well as to industry, other Federal and State

agencies, and academic community. The Technology Catalogue features technologies that have been successfully demonstrated in the field through Integrated Demonstrations (IDs) and are considered sufficiently mature to be used in the near term. The catalogue also discusses the status of the development of these innovative technologies. Forty-three technologies are featured: 22 characterization/monitoring technologies; and 21 remediation technologies.

14A

VOCs in Arid Soils: Technology Summary.
U.S. Department of Energy, Office of Environmental Management, Office of Technology Development, Washington, DC, February 1994

DOE Document Number: DOE/EM-0136P

NTIS Document Number: DE94-008864/XAB

The Office of Technology Development at the U.S. Department of Energy developed cost effective mechanisms for assembling a group of related and synergistic technologies to evaluate their performance individually or as a complete system in correcting waste management and environmental problems from cradle to grave called Integrated Demonstrations. An Integrated Demonstration for Volatile Organic Compounds (VOCs) in Arid Soils is discussed in this document. The document discusses technologies to clean up VOCs and associated contaminants in soil and groundwater at arid sites and includes information on drilling, characterization and monitoring, retrieval of contaminants, above ground treatment of contaminants, and in-ground treatment of contaminants. Technologies discussed include, heavy-weight cone penetrometer drilling, directional drilling, ResonantSonic^{SM} drilling, borehole samplers, halosnifs, portable acoustic wave sensors, unsaturated wave apparatus, and supercritical fluid extraction / field detection. Processes and technologies used to complete them which are discussed include in-well vapor stripping, off-gas membrane separation, supported liquid membranes, steam reforming, turnable hybrid plasma, and in situ bioremediation of groundwater.

STUDIES AND DEMONSTRATIONS

Documents Focusing on Test Design

14B

Combining Treatability Studies and Site Characterization for Rational Design of In Situ Bioremediation Using Nitrate as an Electron Acceptor.
Hutchins, S. R.; Kampbell, D. H.; Cook, M. L.; Pfeffer, F. M.; and Cosby, R. L.; U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, OK, ManTech Environmental Technology, Inc., Ada, OK, Dynamac Corporation, Ada, OK, 1993

EPA Document Number: EPA/600/A-93/172

NTIS Document Number: PB93-221901/XAB

Rational design relates laboratory treatability studies at field scale to the distribution of contaminants and to the residence time of remedial fluids. The electron acceptor is usually the limiting factor in bioremediation. Ideally, the electron acceptor should not be depleted as water or air moves across the region contaminated with oily phase material. When all of the contaminated mass receives adequate supplies of electron acceptor, the course of redemption should parallel that established in the laboratory study. If regions of the contaminated mass are not adequately supplied, the course of remediation at field scale is not predicted in any straightforward way from the laboratory study. Rational design compares the residence time and concentration of electron acceptor at field scale to the demand demonstrated for the electron acceptor in the laboratory to ensure that the engineered implementation of in situ bioremediation is adequate.

14C

Effects of Ground Water Chemistry on Co-Metabolism of Chlorinated Solvents by Methanotrophic Bacteria.
Palumbo, A. V. and Strandberg, G. W., U.S. Department of Energy, Oak Ridge National Laboratory, Oak Ridge, TN, 1990

NTIS Document Number: DE91-014223/XAB

Degradation of chlorinated alkenes such as trichloroethylene (TCE) by methanotrophic bacteria is a promising technology for the remediation of contaminated ground water. Ultimately, the success of this approach may be dependent on the influence of ground-water chemistry on degradation rates and extent. TCE can rapidly be reduced to low levels in laboratory cultures growing on defined media. However, if major changes in ground-water chemistry are necessary to achieve substantial TCE degradation, field application of processes (i.e., above-ground and in situ treatment) may be limited by cost or logistic problems. For example, the presence of competitive inhibitors may limit the extent of TCE degradation. The goal of the research is to quantify the potential effects of ground-water chemistry on the biodegradation of TCE by methanotrophs and to define concentrations of methane that need to be added to the system to produce maximum rates of TCE degradation. This includes evaluation of major nutritional requirements (e.g., PO_4) in addition to the focus on competitive inhibition.

14D

Experimental Evaluation of the Mathematical Model for In Situ Aquifer Restoration Processes.
Short, T. E. and Yeh, G. T., U.S. Environmental Protection

Agency, Robert S. Kerr Environmental Research Laboratory, Ada, OK, Pennsylvania State University, University Park, PA, U.S. Department of Civil Engineering, 1993

EPA Document Number: EPA/600/A-93/147

NTIS Document Number: PB93-212363/XAB

An experimental investigation using an artificial aquifer was conducted on in situ denitrification. Methanol substrate was injected into the aquifer to enable denitrifying bacteria to convert the nitrates into nitrogen. The experiment in the study provided a database that was used to evaluate mathematical simulations of the processes involved. Numerical dispersion was found to be a critical characteristic of the numerical solution technique. Density drive and plugging of the aquifer due to biological growths were found to be important processes that need to be considered in future simulations.

15A

In Situ Bioremediation of Spills from Underground Storage Tanks: New Approaches for Site Characterization, Project Design, and Evaluation of Performance.
Wilkson, J. T; Lowell, E. L., Michalowski, J.; Vandergrift, S.; and Callaway, R., U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, OK, July 1989

EPA Document Number: EPA/600/S2-89/042

NTIS Document Number: PB89-219976/XAB

This report presents a systematic approach for the design of in situ bioremediation of hydrocarbon contamination in ground water from the determination of the total quantity of hydrocarbons in the aquifer to the utilization of that information in an actual field demonstration. This report explains why the total quantity of hydrocarbons in an aquifer can only be determined by collecting cores. A procedure to acquire cores from a contaminated aquifer is described. The procedures described in the report were field tested in designing a demonstration of the bioremediation of an aviation gasoline leak. The performance of the demonstration was consistent with the expected performance based on the preliminary site characterization using the described procedures.

15B

In Situ Redox Manipulation: Enhancement of Contaminant Destruction and Immobilization.
Fruchter, J. S., Battelle Pacific Northwest Laboratories, Richland, WA, U.S. Department of Energy, Washington, DC, January 1993

NTIS Document Number: DE93-007877/XAB

This report discusses a project to develop, test, and evaluate in situ methods for immobilizing inorganic contaminants (metals, inorganic ions, and radionuclides) and destroying nitrates organic contaminants, (primarily chlorinated hydrocarbons). This research work is being performed for the U.S. Department of Energy through the In Situ Remediation Integrated Program.

15C

Methodologies for Evaluating In Situ Bioremediation of Chlorinated Solvents, Research Report 21, August 19, 1989 - June 19, 1991.
Semprini, L.; Grbic-Galic, D.; McCarty, P. L.; and Roberts, P. V.; Stanford University, CA, U.S. Department of Civil Engineering, U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, OK, March 1992

EPA Document Number: EPA/600/R-92/042

NTIS Document Number: PB92-146943/XAB

The report summarizes the behavior of and requisite conditions for a class of natural biological processes that can transform chlorinated aliphatic compounds. These compounds are among the most prevalent hazardous chemical contaminants found in municipal and industrial wastewaters, landfills and landfill leachates, industrial disposal sites, and ground water. Biological degradation is one approach that has the potential for destroying hazardous chemicals so that they can be rendered harmless for all time. Methodologies are presented that are useful for evaluating the potential for biorestoration of ground water contaminated with chlorinated aliphatic compounds. Section 1 provides an introduction and an overview of the problems with chlorinated aliphatic compounds in ground water. Section 2 presents a review of the processes affecting the movement and fate of chlorinated aliphatics in the subsurface, including advection, dispersion, sorption and relative mobility, diffusional transport, and immiscible transport. Methodologies and results are presented for evaluating the presence of a native methantrophic community and its ability to degrade the contaminants of concern, determining the sorption of contaminants to the aquifer material, and preliminary designing of an in situ treatment approach using the model previously described.

15D

Novel Closed Loop Air Stripping Process for VOC Removal from Contaminated Water, Final Report.
Bhowmick, M.; Sontag, T. K.; and Semmens, M. J.; Minnesota University, Minneapolis, MN, Department of Civil and Mineral Engineering, U.S. Geological Survey, Water Resources Division, Reston, VA, December 1990

NTIS Document Number: PB92-218247/XAB

The study presents an approach for the treatment of contaminated ground water, which includes Volatile Organic Compounds (VOCs) stripped from the water using hollow fiber membranes or using conventional air stripping technology and then the VOCs are oxidized in the gas phase using UV oxidation or a combination of photo oxidation and photo-catalysis with Titanium Dioxide (TiO_2). The work on the photooxidation of VOCs is applicable to both water and soil treatment techniques, such as air stripping and in situ vacuum extraction. The study is divided into five major segments. Each segment includes relevant sections on the experimental methods employed, the results from the tests conducted, the development of models, and the conclusions that were drawn from the work.

16A

Office of Technology Development Integrated Program for Development of In Situ Remediation Technologies.
Peterson, M., Battelle Pacific Northwest Laboratories, Richland, WA, U.S. Department of Energy, Washington, DC, August 1992

NTIS Document Number: DE93-001312/XAB

The Department of Energy's Office of Technology Development has instituted an integrated program focused on development of in situ remediation technologies. The development of in situ remediation technologies will focus on five problem groups: buried waste, contaminated soils, contaminated ground water, containerized wastes, and underground detonation sites. The contaminants that will be included in the development program are volatile and nonvolatile organics, radionuclides, inorganics, and highly explosive materials, as well as mixtures of these contaminants. The In Situ Remediation Integrated Program (ISRIP) has defined the fiscal year 1993 research and development technology areas for focusing activities, and they are described in this paper. These R&D topical areas include: nonbiological in situ treatment, in situ bioremediation, electrokinetics, and in situ containment.

16B

Preliminary Evaluation of Selected In Situ Remediation Technologies for Volatile Organic Compounds Contamination at Arid Sites.
Lenhard, R. J.; Gerber, M. A.; and Amonette, J. E., Battelle Pacific Northwest Laboratories, Richland, WA, U.S. Department of Energy, Washington, DC, October 1992

NTIS Document Number: DE93-002182/XAB

To support the Volatile Organic Compounds-Arid Site (VOC-Arid) Integrated Demonstration (ID) in its technical, logistical, institutional, and economical testing of emerging environmental management and restoration technologies, Pacific Northwest Laboratory is evaluating several in situ remediation technologies for possible inclusion in the demonstration. The evaluations are made with respect to the initial focus of the VOC-Arid ID: the carbon tetrachloride contamination at the Hanford Site, where it was disposed to the vadose zone along with other volatile and nonvolatile organic wastes, heavy metals, acids, and radionuclides. The purposes of this report are (1) to identify candidate in situ technologies for inclusion in the program, (2) to evaluate the candidate technologies based on their potential applicability to VOC contamination at arid sites and geologic conditions representative of the ID host site (i.e., Hanford Site), and (3) to prioritize those technologies for future U.S. Department of Energy support.

16C

***Savannah River:* Horizontal Wells for In Situ Remediation of Ground Water and Soils.**
Kaback, D. S.; Looney, B. B.; Corey, J. C.; Wright, L. M.; and Steele, J. L., DuPont de Nemours (E.I.) and Company, Aiken, SC, Sirrine Environmental Consultants, Greenville, SC, U.S. Department of Energy, Savannah River Laboratory, Aiken, SC, 1989

NTIS Document Number: DE89-010456/XAB

Two horizontal wells were installed adjacent to an abandoned process sewer line at the Savannah River Plant. Documented leaks from the process sewer have contaminated the underlying vadose zone and ground water with volatile organic compounds. The wells were installed to test new methods of in situ remediation of soils and ground water. A deep horizontal well, installed below the water table, is to be used as an air-injection well to strip volatile organics from the contaminated ground water. The shallow horizontal well, installed in the vadose zone, is to be used to remove vapor-phase volatile organic compounds from the vadose zone and to recover the organics purged from the ground water. Horizontal wells were selected for injection and extraction because this geometry should maximize the surface area available for in situ remediation reactions to occur. Target zones for the lateral well screens were selected on the basis of (1) concentrations of volatile organic compounds in ground water from nearby monitoring wells, and (2) porosity and permeability of the sediments as determined by core analysis, geophysical logs, and sieve analyses.

16D

***Savannah River:* In Situ Remediation System for Contaminated Ground Water, Patent Application.**
Corey, J. C.; Looney, B. B.; and Kaback, D. S., U.S. Department of Energy, Savannah River Laboratory, Aiken, SC, August 1988

NTIS Document Number: DE91-017331/XAB

A system for removing volatile contaminants from a subsurface plume of contamination comprising two sets of wells, a well for injecting a fluid into a saturated zone on one side of the plume and an extracting well for collecting the fluid together with volatilized contaminants from the plume on the other side of the plume, is described. The fluid enables the volatile contaminants to be volatilized and carried through the ground to the extracting well. Injecting and extracting wells are preferably horizontal wells positioned below the plume in the saturated zone and above the plume in the vadose zone. The fluid may be air or other gas or a gas and liquid mixture depending on the type of contaminant to be removed and may be preheated to facilitate volatilization. Treatment of the volatilized contamination may be by filtration, incineration, atmospheric dispersion, or the like.

17A

***Savannah River:* Test Plan for In Situ Bioremediation Demonstration of the Savannah River Integrated Demonstration Project, DOE/OTD TTP No. SR 0566-01. Revision 3.**

Hazen, T. C.; Westinghouse Savannah River Company, Aiken, SC, U.S. Department of Energy, Washington, DC, September 1991

NTIS Document Number: DE92-013973/XAB

This project is designed to demonstrate in situ bioremediation of ground water and sediment contaminated with chlorinated solvents. Indigenous microorganisms will be simulated to degrade trichloroethylene (TCE), tetrachloroethylene (PCE) and their daughter products in situ by addition of nutrients to the contaminated zone. In situ biodegradation is a highly attractive technology for remediation because contaminants are destroyed, not simply moved to another location or immobilized, thus decreasing costs, risks, and time, while increasing efficiency and public and regulatory acceptability. Bioremediation has been found to be among the least costly technologies in applications where it will work.

17B

Solvent Extraction for Remediation of Coal Tar Sites, Final Report.

Luthy, R. G.; Dzombak, D. A.; Peters, C.; Ali, M. A.; and Roy, S. B., Carnegie-Mellon University, Department of Civil Engineering, Pittsburgh, PA, U.S. Geological Survey, Water Resources Division, Reston, VA, September 1992

NTIS Document Number: PB93-118347/XAB

The report presents the results of an initial assessment of the feasibility of solvent extraction for removing coal tar from the subsurface or for treating contaminated soil excavated at manufactured gas plant (MGP) sites. In situ solvent extraction would involve injection, recovery, and reclamation for reinjection of an environmentally-benign, water-miscible solvent. Both laboratory experiments and engineering evaluations were performed to provide a basis for the initial feasibility assessment. Laboratory work included identification and evaluation of promising solvents, measurement of fundamental properties of coal tar-solvent-water systems, and measurement of rates of dissolution of coal tar in porous media into flowing solvent-water solutions. Engineering evaluations involved identification of common hydrogeologic features and contaminant distributions at MGP sites, and identification and evaluation of possible injection-recovery well deployment schemes.

STUDIES AND DEMONSTRATIONS (CONT'D)

Documents Focusing on Study Results

17C

Applied Geologic, Microbiological, and Engineering Constraints of In Situ BTEX Bioremediation, Journal Article: Published in *Remediation*, v3n1, pg. 83-110, Winter 1992-1993.

Kennedy, L. G. and Hutchins, S. R., U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, OK, American Environmental Consultants, Inc., Norman, OK, February 1993

EPA Document Number: EPA/600/J-92/450

NTIS Document Number: PB93-141513/XAB

An in situ bioremediation project has been designed and constructed for a site in south-central Kansas just north of Wichita. A pipeline leaked an unknown quantity of refined fuels in the 1970s. The spill was undetected until hydrocarbons were found in a nearby municipal water supply well. Of concern, from a regulatory perspective, are the alkylbenzene components found in the ground water, including benzene, toluene, ethylbenzene, and xylene (BTEX). Initial abatement procedures, including free product removal and pumping, had become ineffective. In situ bioremediation was selected to complete the restoration process. The project emphasizes the need for a strong understanding of the geologic and hydrogeologic conditions prevalent under the site. Site studies were conducted to determine the distribution and mass of the contaminant and the hydraulic regime. Laboratory microbial studies were used to determine the efficacy of nitrate as a primary electron acceptor. Information from site studies was used to design a treatment system tailored to the requirements of the site. The treatment system is designed to deliver the maximum amount of nutrient-enriched water to the contaminated zone while maintaining hydraulic control of the site.

18A

A Process for Contaminant Removal and Waste Volume Reduction to Remediate Groundwater Containing Certain Radionuclides, Toxic Metals, and Organics, Final Report.

Buckley, L. P.; Killey, D.; Vijayan, S.; and Wong, P., Argonne National Laboratory, Chemical Technology Division, August 1993

DOE Document Number: DOE/CH-9201

A project to remove groundwater contaminants by an improved treatment process was performed during October 1990 to March 1992 by Atomic Energy of Canada Limited for the United States Department of Energy, managed by Argonne National Laboratory. The goal was to generate high-quality effluent while minimizing secondary waste volume. Two effluent target levels, within an order of magnitude or less of the U.S. Drinking Water Limit, were set to judge the process effectiveness. The program employed mixed waste feeds containing cadmium, uranium, lead, iron, calcium, strontium-85-90, cesium-137, benzene, and trichloroethylene in simulated and actual groundwater and soil leachate solutions. A combination of process steps that included sequential chemical conditioning, cross-flow microfiltration and dewatering by low temperature-evaporation, and filter pressing were effective for the treatment of mixed waste having diverse physicochemical properties. Overall test results revealed a three-step chemical treatment / microfiltration sequence combined with a final dewatering step is optimal.

18B

Characteristics of the Volatile Organic Compounds — Arid Integrated Demonstration Site.

Last, G. V.; Lenhard, R. J.; Bjornstad, B. N.; Evans, J. C.; and Roberson, K. R., Battelle Pacific Northwest Laboratories, Richland, WA, U.S. Department of Energy, Washington, DC, October 1991

NTIS Document Number: DE92-003882/XAB

The Volatile Organic Compounds — Arid Integrated Demonstration Program (VOC-Arid ID) is targeted at demonstration and testing of technologies for the evaluation and cleanup of volatile organic compounds and associated contaminants at arid DOE sites. The initial demonstration site is an area of carbon tetrachloride (CCl_4) contamination located near the center of the Hanford Site. The movement of CCl_4 and other volatile organic contaminants in the subsurface is very complex. The problem at the Hanford Site is further complicated by the concurrent discharge of other waste constituents including acids, lard oil, organic phosphates, and transuranic radionuclides. In addition, the subsurface environment is very complex, with large spatial variabilities in hydraulic properties. A thorough understanding of the problem is essential to the selection of appropriate containment, retrieval, and/or in situ remedial technologies. The effectiveness of remedial technologies depends on knowing where the contaminants are; how they are hold up in a given physical and chemical subsurface environment; and knowing the physical, chemical, and microbiological changes that are induced by the various remedial technologies.

18C

Chemical Enhancements to Pump-and-Treat Remediation.

Palmer, C.D. and Fish, W., Robert S. Kerr Environmental Laboratory, Ada, OK, U.S. Environmental Protection Agency, Office of Research and Development, Office of Solid Waste and Emergency Response, Technology Innovation Office, Washington, DC, January 1992

EPA Document Number: EPA/540/S-92/001

NTIS Document Number: PB92-180074

The document looks into the use of chemical enhancement to improve ground-water remediation efficiencies using pump-and-treat technologies and points out arenas of contamination where such techniques are not practical. While various chemical enhancement methods must be evaluated with regard to specific site conditions, there are general concepts applicable to all chemical enhancement methods, and they are discussed in this document. In addition, this document poses key questions that should be answered before any chemical-enhancement scheme is initiated and stimulates discussion on the merits and limitations of chemical enhancement methods.

18D

Comparison of Bioventing and Air Sparging for In Situ Bioremediation of Fuels.

Kampbell, D. H.; Griffin, C. J.; and Blaha, F. A., U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, OK, Solar Universal Technologies, Inc., Traverse City, MI, Coast Guard Civil Engineering Unit, Cleveland, OH, 1993

EPA Document Number: EPA/600/A-93/178

NTIS Document Number: PB93-221968/XAB

Bioremediation pilot-scale subsurface venting and sparging systems were operated at a low aeration rate at an aviation gasoline spill site. Bioventing removed 99 percent of vadose zone contamination in eight months with minimal surface emissions. The biosparging process is presently operating and has removed one-third of oily phase residue below the water

table in one year. The ground-water plume has been cleansed of benzene, toluene, ethylbenzene, and xylene (BTEX) components by sparging.

19A

E.I. DuPont De Nemours & Company/Oberlin Filter Company Microfiltration Technology: Applications Analysis Report.
U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, Cincinnati, OH, October 1991

EPA Document Number: EPA/540/A5-90/007

NTIS Document Number: PB92-119023/XAB

This document discusses the Superfund Innovative Technology Evaluation (SITE) Program Demonstration of the DuPont/Oberlin microfiltration technology. This document evaluates the microfiltration technology's ability to remove metals (present in soluble or insoluble form) and particulates from liquid wastes while producing a dry filter cake and a filtrate that meet applicable disposal requirements. In addition, it presents economic data from the SITE demonstration, and discusses the potential applicability of the technology. The DuPont/Oberlin microfiltration technology combines Oberlin's automatic pressure filter with DuPont's new microporous Tyvek filter media. It is designed to remove particles that are 0.1 micron in diameter, or larger, from liquid wastes, such as contaminated ground water. This report also summarizes the results from three case studies. All three facilities treated process waste waters containing metals and total suspended solids (TSS) ranging from several parts per million to several percent.

19B

Enhanced Bioremediation Utilizing Hydrogen Peroxide as a Supplemental Source of Oxygen: A Laboratory and Field Study.
U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, OK, February 1990

EPA Document Number: EPA/600/S-29/006

NTIS Document Number: PB90-183435/XAB

Laboratory and field-scale studies were conducted to investigate the feasibility of using hydrogen peroxide as a supplemental source of oxygen for bioremediation of an aviation gasoline fuel spill. Ground water data from the enhanced in situ bioremediation pilot field study indicates that hydrogen peroxide successfully increased the concentration of available oxygen downgradient. In this study, however, it was observed that there was a measurable increase of oxygen in the soil gas area where hydrogen peroxide was injected. This indicated that a significant fraction of hydrogen peroxide rapidly decomposed to oxygen gas and escaped into the unsaturated zone.

19C

Experimental Examination of Integrated Soil Vapor Extraction Techniques, Journal Article: Published in *Proceedings of the Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection, and Restoration*, pg. 441-452, November 1992.
Johnson, R. L.; Bagby, W.; Perrott, M.; and Chen, C. T., Oregon Graduate Institute of Science and Technology, Department of Environmental Science and Engineering, Beaverton, OR, U.S. Environmental Protection Agency, Risk Reduction Engineering Laboratory, Cincinnati, OH, 1992

EPA Document Number: EPA/600/J-92/280

NTIS Document Number: PB93-131738/XAB

Soil vapor extraction (SVE) has been shown to be effective at removing hydrocarbons from the unsaturated zone. However, at many spill sites significant fractions of the mass are at or below the water table, in which case SVE is far less effective. To improve its efficiency in cases where gasoline is trapped below the water table, SVE can be used in conjunction with other techniques to get at that trapped mass. In the last few years the direct injection of air into the formation below the water table (i.e., in situ sparging) has become a popular technique. Another approach is to lower the water table to improve airflow in the vicinity of the trapped product. This can be accomplished either in the localized area of a ground water draw down cone or as the result of larger scale dewatering. In experiments conducted at the Oregon Graduate Institute (OGI), hydrocarbon spills into a large three-dimensional physical model filled with sand are being used to study the efficiencies of SVE combined with other techniques. Experiments to date have examined SVE operating as a stand-alone technique, as well as in conjunction with air sparging below the water table, dewatering of the "smear zone" (i.e., where product is trapped as residual below the water table), and air injection into the dewatered smear zone.

19D

Feasibility of Biodegradation of Tetrachloroethylene in Contaminated Aquifers, Final Report.
Fogel, S., Cambridge Analytical Associates, Inc., Bioremediation Systems Division, Boston, MA, National Science Foundation, Division of Industrial Science and Technological Innovation, Washington, DC, September 16, 1988

NTIS Document Number: PB91-199778/XAB

Tetrachloroethylene (TCE), a solvent and de-greasing agent, is widely spilled and disposed of on soil. It is easily transported in ground water, causing wide-spread aquifer contamination. Conventional technology for the treatment of solvent-contaminated aquifers, which involves pumping out the water and above-ground treatment by physical/chemical techniques, is slow and expensive. Cambridge Analytical Associates Bioremediation Systems has carried out experiments to demonstrate the feasibility of in situ biodegradation of TCE. The process would involve controlled addition of nutrients to the ground water to stimulate the activity of naturally occurring bacteria. A 23 liter laboratory aquifer simulator was constructed and filled with soil, and amended ground water was recirculated throughout the soil. Methanogenic conditions were brought about in the reactor within 15 days and TCE was shown to degrade rapidly to dichloroethylene. Oxygen was then introduced and the oxidation of dichlororethylene by methanotrophic bacteria was initiated. The aquifer simulator experiment indicated that aquifer conditions can be manipulated in situ to bring about the complete degradation of TCE.

20A

Influence of Microbial Transport Processes on "In Situ" Biodegradation of Ground Water Contaminants, Technical Progress Report, Final.

Cunningham, A. B. and Characklis, W. G.; Montana State University, Bozeman Institute for Biological and Chemical Process Analysis, MT, U.S. Geological Survey, Water Resources Division, Reston, VA, 1991

NTIS Document Number: PB91-234732/XAB

A fundamental understanding of both transport and transformation processes is essential to the development of technically sound remediation strategies for ground water contamination. Accordingly, the goal of the project is to enhance the rate and efficiency of in situ microbial degradation of subsurface contaminants through an improved understanding of processes that govern transport, attachment, growth, and activity of microorganisms in porous media. The report is organized into the following sections: 1) Transport Processes: contains experimental methods and results that document the effect of biofilm accumulation on the transport of water, nutrients, and suspended cells in one-dimensional porous media flow reactions, 2) Effects of Cell Starvation and Motility: presents experimental procedures and results describing transport characteristics of starved vs. growing and motile vs. nonmotile cells in porous media, 3) Modeling Microbial Transport and Activity: describes development of a mathematical model that simulates contaminant biodegradation/biosorption, nutrient depletion and biomass accumulation in one-dimensional porous media flow, and 4) Bioremediation Guidelines: summarize relevant information in the form of guidelines useful to decision-makers concerned with bioremediation of contaminated water and soil.

20B

In Situ Biodegradation Treatment.

U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, Office of Research and Development, Cincinnati, OH, April 1994

EPA Document Number: EPA/540/S-94/502

In situ biodegradation may be used to treat low-to-intermediate concentrations of organic contaminants in place without disturbing or displacing the contaminated media. Although this technology has been used to degrade a limited number of inorganics, specifically cyanide and nitrate, in situ biodegradation is not generally employed to degrade inorganics or to treat media contaminated with heavy metals. During in situ biodegradation, electron acceptors (e.g., oxygen and nitrate), nutrients, and other amendments may be introduced into the soil and groundwater to encourage the growth of an indigenous population capable of degrading the contaminants of concern. These supplements are used to control or modify site-specific conditions that impede microbial activity and, thus, the rate and extent of contaminant degradation. Depending on site-specific clean-up goals, in situ biodegradation can be used as the sole treatment technology or in conjunction with other biological, chemical, and physical technologies in a treatment-train. In the past, in situ biodegradation has often been used to enhance traditional pump and treat technologies. As of Fall 1993, in situ biodegradation was being considered or implemented as a component of the remedy at 21 Superfund sites and 38 RCRA, Underground Storage Tank, Toxic Substances Control Act, and Federal sites with soil, sludge, sediment, or groundwater contamination. This bulletin provides information on the technology's applicability, the types of residuals produced, the latest performance data, the site requirements, the status of the technology, and sources for further information.

20C

In Situ Bioremediation of Hanford Ground Water.

Skeen, R. S.; Roberson, K. R.; Workman, D. J.; Petersen, J. N.; and Shouche, M., Battelle Pacific Northwest Laboratories, Richland, WA, U.S. Department of Energy, Washington, DC, April 1992

NTIS Document Number: DE92-012350/XAB

Liquid wastes containing radioactive, hazardous, and regulated chemicals have been generated throughout the 40+ years of operations at the U.S. Department of Energy's (DOE) Hanford Site. Some of these wastes were discharged to the soil column and many of the waste components, including nitrate, carbon tetrachloride (CCl_4), and several radionuclides, have been detected in the Hanford ground water. Current DOE policy

prohibits the disposal of contaminated liquids directly to the environment, and remediation of existing contaminated ground waters may be required. In situ bioremediation is one technology currently being developed at Hanford to meet the need for cost effective technologies to clean ground water contaminated with CCl_4, nitrate, and other organic and inorganic contaminants. This paper focuses on the latest results of an ongoing effort to develop effective in situ remediation strategies through the use of predictive simulations.

21A

In Situ Generation of Oxygen By Electrolysis and the Electrochemical Effects on Microorganisms' Population, Final Report, September 19, 1990- November 19, 1991.
Han, M. K.; Wyza, R. E.; and Olfenbuttel, R. F., Battelle Columbus Laboratories, OH, Naval Civil Engineering Laboratory, Port Hueneme, CA, June 1992

NTIS Document Number: AD-A252 358/7/XAB

The objective of this program was to quantitatively assess the effectiveness of in situ electrolysis of ground water on the growth of soil microorganisms. The electrolysis method was used to supply oxygen to soil microorganisms to enhance bioremediation of sites that are contaminated with hydrocarbons. Electrochemical tests were performed with two different types of soils in a 10-gallon glass container. Experimental variables examined included driving voltage, current, and electrode spacing. Stainless steel mesh was used for both the anode and the cathode. Depending on the soil, a sustained supply of dissolved oxygen up to 16 ppm was achieved. The population of soil microorganisms increased with increasing the oxygen content in the ground water. A slight decrease in the population was seen at the cathode, which might have been due to an increase in the pH at the cathode.

21B

In Situ Steam Extraction Treatment, Engineering Bulletin.
Science Applications International Corporation, Cincinnati, OH, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Office of Emergency and Remedial Response, Washington, DC, May 1991

EPA Document Number: EPA/540/2-91/005

NTIS Document Number: PB91-228064/XAB

In situ steam extraction removes volatile and semivolatile hazardous contaminants from soil and ground water without excavation of the hazardous waste. Waste constituents are removed in situ by the technology and are not actually treated. The use of steam enhances the stripping of volatile contaminants from soil and can be used to displace contaminated ground water under some conditions. The resultant condensed liquid contaminants can be recycled or treated prior to disposal. The steam extraction process is applicable to organic wastes but has not been used for removing insoluble inorganics and metals. Steam is injected into the ground to raise the soil temperature and drive off volatile contaminants. Alternatively, steam can be injected to form a displacement front by steam condensation to displace ground water. The contaminated liquid and steam condensate are then collected for further treatment. Two types of systems are discussed in the document: 1) the mobile system and 2) the stationary system. The bulletin provides information on the technology applicability, limitations, a description of the technology, types of residuals produced, site requirements, the latest performance data, the status of the technology, and sources for further information.

21C

Laboratory Evaluation of the In Situ Chemical Treatment Approach for Remediation of Contaminated Soils and Ground Water.
Thorton, E. C.; Jurgensmeier, C. A.; and Baechler, M. A., Westinghouse Hanford Company, Richland, WA, U.S. Department of Energy, Washington, DC, October 1991

NTIS Document Number: DE93-006901/XAB

Bench-scale solution and soil tests were conducted in a proof of principle demonstration of the in situ chemical treatment approach to the remediation of metal and radionuclide contaminated soil and ground water. These tests were directed specifically towards treatment of Cr_6 contaminated solutions and unsaturated soil as an application of the approach. Testing was planned and conducted to provide general information relating treatment agent concentrations to effect. This approach served to define the amount of a specific agent required to achieve acceptable results and provided information regarding treatment rates and pH effects associated with the treatment reactions.

21D

Performance Evaluation of a Ground Water and Soil Gas Remedial Action.
Hansen, M. C. and Hartnett, S. L., U.S. Department of Energy, Argonne National Laboratory, IL, July 1990

NTIS Document Number: DE90-017659/XAB

Volatile organic compounds (VOCs) continue to be remediated by a ground-water extraction system and an in situ vapor extraction system at a Midwest agricultural site. Carbon tetrachloride (CCl_4) and chloroform ($CHCl_3$) contamination levels were detected at maximum concentrations of 4000 parts per billion (ppb) and 360 ppb, respectively, for on-site groundwater samples and 6000 ppb and 1800 ppb, respectively, for on-

site gas samples. Ground water from a domestic well and a monitoring well located at least 2300 ft. downgradient from the site also had CCl_4 and $CHCl_3$ contamination. Furthermore, a public water supply well, located downgradient of the site, was found to have ground water contaminated with CCl_4. During two years of operation of the remedial action, ground-water and soil gas samples have been analyzed to monitor potential migration of contaminants from the site and to track the overall progress toward cleanup. Results demonstrate a decrease in ground-water contamination in both on- and off-site monitoring wells and a decrease in soil gas air emissions from the site. This paper presents the sampling results for the site over the last two years and discusses trends indicating the effectiveness of the remedial action system in controlling contaminant migration and overall progress toward reducing the source of contamination in the unsaturated subsoils.

22A

perox-pure™ Chemical Oxidation Technology Peroxidation Systems, Inc.: Applications Analysis Report.

U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, Cincinnati, OH, July 1993

EPA Document Number: EPA/540/AR-93/501

NTIS Document Number: PB94-130325/XAB

This document discusses the Superfund Innovative Technology Evaluation (SITE) Program Demonstration of the perox-pure™ chemical oxidation technology's ability to remove volatile organic compounds (VOC) and other organic contaminants present in liquid wastes. The perox-pure™ chemical oxidation technology was developed to destroy dissolved organic contaminants in water. The technology uses ultraviolet (UV) radiation and hydrogen peroxide to oxidize organic compounds present in water at parts per million levels or less. This treatment technology produces no air emissions and generates no sludge or spent media that require further processing, handling, or disposal. Economic data and the results from three case studies are also summarized in this report. The contaminants of concern in these case studies include acetone, isopropyl alcohol (IPA), TCE, and pentachlorophenol (PCP).

22B

Reductive Dehalogenation: A Subsurface Bioremediation Process, Journal Article: Published in *Remediation*, Winter 1990-1991.

Sims, J. L.; Suflita, J. M.; and Russell, H. H., U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, OK, Utah Water Research Laboratory, Logan, OK, Oklahoma University, Department of Botany and Microbiology, Norman, OK, 1990

EPA Document Number: EPA/600/J-90/259

NTIS Document Number: PB91-144873/XAB

Introduction and large-scale production of synthetic halogenated organic chemicals over the last 50 years has resulted in a group of contaminants that tend to persist in the environment and resist both biotic and abiotic degradation. The low solubility of these types of contaminants, along with their toxicity and tendency to accumulate in food chains, make them particularly relevant targets for remediation activities. Among the mechanisms that result in dehalogenation of some classes of organic contaminants are stimulation of metabolic sequences through introduction of electron donor and acceptor combinations, addition of nutrients to meet the needs of dehalogenating microorganisms, possible use of engineered microorganisms, and use of enzyme systems capable of catalyzing reductive dehalogenation. The current state of research and development in the area of reductive dehalogenation is discussed along with possible technological application of relevant processes and mechanisms to remediation of soil and ground water contaminated with chlorinated organics. In addition, an overview of research needs is suggested, which might be of interest for development of in situ systems to reduce the mass of halogenated organic contaminants in soil and ground water.

22C

Removal of Radionuclides by Electrokinetic Soil Processing, Journal Article: Published in *Journal of the National Technical Association*, Spring 1993.

Parker, R. A., U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, Cincinnati, OH, 1993

EPA Document Number: EPA/600/J-93/296

NTIS Document Number: PB93-222875/XAB

Electrokinetics promises to be an innovative treatment process for in situ treatment of soils and ground water contaminated with heavy metals and radionuclides. Electrokinetics refers to the movement of ionic liquids and charged particles relative to one another under the action of an applied direct current electric field. The paper summarizes the results of laboratory tests for the removal of uranium, thorium, and radium, conducted from February 28, 1991, to March 30, 1991, and a review of progress to date.

22D

Retrospective Performance Evaluation on In Situ Bioremediation: Site Characterization.

Wilson, J. T. and Kampbell, D. H., Robert S. Kerr Environmental Research Laboratory, Ada, OK, 1993

EPA Document Number: EPA/600/A-93/173

NTIS Document Number: PB93-221919/XAB

Performance of in situ bioremediation was demonstrated at a shallow water site with subsurface contamination of used crank case oil, diesel fuel, gasoline, and other oily phase products. Treatment involved ground-water amendment by hydrogen peroxide and nutrients by a recharge gallery. The system was operated for 2 1/2 years. During treatment benzene and total BTEX concentrations in ground water were reduced in magnitude exceeding ten and twenty times, respectively. Vertical profile core samples showed a two-feet thick interval near the water table containing significant amounts of hydrocarbons. The center of the interval had not been depleted of BTEX compounds, but the surrounding cortex had been physically and biologically weathered. The interval material was fine textured which restricted flow of remedial fluids resulting in little opportunity for bioremediation.

23A

***Savannah River:* Field Demonstration of In Situ Air Stripping Using Horizontal Wells.**
Looney, B. B. and Kaback, D. S., Westinghouse Savannah River Company, Aiken, SC, U.S. Department of Energy, Washington, DC, 1991

NTIS Document Number: DE92-009963/XAB

Under sponsorship from the U.S. Department of Energy, technical personnel from the Savannah River Laboratory and other DOE laboratories, universities, and private industry have completed a full scale demonstration of environmental remediation using horizontal wells. The 139-day long test was designed to remove volatile chlorinated solvents from the subsurface using two horizontal wells. One well, approximately 90 m long and 45 m deep drilled below a contaminant plume in the ground water, was used to inject air and strip the contaminants from the ground water. A second horizontal well, approximately 50 m long and 20 m deep in the vadose zone, was used to extract residual contamination in the vadose zone along with the material purged from the ground water. The test successfully removed approximately 7250 kg of contaminants. A large amount of characterization and monitoring data was collected to aid in interpretation of the test and to provide the information needed for future environmental restorations that employ directionally drilled wells as extraction or delivery systems.

23B

***Savannah River:* Full-scale Field Test of the In Situ Air Stripping Process at the Savannah River Integrated Demonstration Test Site.**
Looney, B. B.; Hazen, T. C.; Kaback, D. S.; and Eddy, C. A., Westinghouse Savannah River Company, Aiken, SC, U.S. Department of Energy, Washington, DC, June 1991

NTIS Document Number: DE92-009749/XAB

Under sponsorship from the U.S. Department of Energy, technical personnel from the Savannah River Laboratory (SRL) and other DOE laboratories, universities, and private industry have completed a full-scale demonstration of environmental remediation using horizontal wells. This demonstration was performed as Phase I of an Integrated Demonstration Project designed to evaluate innovative remediation technologies for environmental restoration of sites contaminated with organic contaminants. The demonstration utilized two directionally drilled horizontal wells to deliver gases and extract contaminants from the subsurface. The resulting in situ air stripping process was designed to remediate soils and sediments above and below the water table as well as ground water contaminated with volatile organic contaminants. The 139-day long test successfully removed volatile chlorinated solvents from the subsurface using the two horizontal wells. One well, approximately 300 ft (90 m) long and 165 ft (50 m) deep drilled below a contaminant plume in the ground water, was used to inject air and strip the contaminants from the ground water. A second horizontal well, approximately 175 ft (53 m) long and 75 ft (23 m) deep in the vadose zone, was used to extract residual contamination in the vadose zone along with the material purged from the ground water. Pre-test and post-test characterization data and monitoring data during the demonstration were collected to aid in interpretation of the test and to provide the information needed for future environmental restoration that employs directionally drilled wells as extraction or delivery systems. Contaminant concentration data and microbiological monitoring data are summarized in this report; the characterization data and geophysical monitoring data are documented in a series of related project reports.

23C

***Savannah River:* Ground Water and Soil Remediation: In Situ Air Stripping Using Horizontal Wells.**
Kaback, D. S.; Looney, B. B.; Eddy, C. A.; and Hazen, T. C., Westinghouse Savannah River Company, Aiken, SC, U.S. Department of Energy, Washington, DC, 1990

NTIS Document Number: DE92-009906/XAB

An innovative environmental restoration technology, in situ air stripping, has been demonstrated at the U.S. Department of Energy (DOE) Savannah River Site (SRS) in South Carolina. This process, using horizontal wells, is designed to concurrently remediate unsaturated-zone soils and ground water containing volatile organic compounds (VOCs). In situ technologies have the potential to substantially reduce costs and time required for remediation, as well as improve effectiveness of remediation. Horizontal wells were selected to deliver and

extract fluids from the subsurface because their geometry can maximize the efficiency of a remediation system and they have great potential for remediating contaminant sources under existing facilities. The first demonstration of this new technology was conducted for a period of twenty weeks. A vacuum was first drawn on the vadose zone well until a steady-state removal of VOCs was obtained. Air was then injected at three different rates and at two different temperatures. An extensive characterization program was conducted at the site and an extensive monitoring network was installed prior to initiation of the test. Significant quantities of VOCs have been removed from the subsurface (equivalent to an eleven-well, 500-gpm, pump-and-treat system at the same site). Concentrations of VOCs in the ground water have been significantly reduced in a number of the monitoring wells.

24A

***Savannah River:* Immunological Techniques as Tools to Characterize the Subsurface Microbial Community at a Trichloroethylene Contaminated Site.**
Fliermans, C. B.; Dougherty, J. M.; Franck, M. M.; McKinzey, P. C.; and Hazen, T. C., Westinghouse Savannah River Company, Aiken, SC, U.S. Department of Energy, Washington, DC, 1992

NTIS Document Number: DE93-007443/XAB

Effective in situ bioremediation strategies require an understanding of the effects pollutants and remediation techniques have on subsurface microbial communities. Therefore, detailed characterization of a site's microbial communities is important. Subsurface sediment borings and water samples were collected from a trichloroethylene (TCE)-contaminated site, before and after horizontal well in situ air stripping and bioventing, as well as during methane injection for stimulation of methane-utilizing microorganisms. Subsamples were processed for heterotrophic plate counts, acridine orange direct counts (AODC), community diversity, direct fluorescent antibodies (DFA) enumeration for several nitrogen-transforming bacteria, and Biolog (regsign) evaluation of enzyme activity in collected water samples. Plate counts were higher in near-surface depths than in the vadose zone sediment samples. During the in situ air stripping and bioventing, counts increased at or near the saturated zone and remained elevated throughout the aquifer, but did not change significantly after the air stripping. Sporadic increases in plate counts at different depths as well as increased diversity appeared to be linked to differing lithologies. AODCs were orders of magnitude higher than plate counts and remained relatively constant with depth except for slight increases near the surface depths and the capillary fringe. Nitrogen transforming bacteria, as measured by serospecific DFA, were greatly affected both by the in situ air stripping and the methane injection. Biolog (regsign) activity appeared to increase with subsurface stimulation both by air and methane. The complexity of subsurface systems makes the use of selective monitoring tools imperative.

24B

***Savannah River:* Savannah River Integrated Demonstration Program.**
Westinghouse Savannah River Company, Aiken, SC, U.S. Department of Energy, Washington, DC, 1991

NTIS Document Number: DE92-009587/XAB

Leakage of solvents (trichloroethylene and tetrachloroethylene) from an underground process sewer line has contaminated soils and underlying ground water at the Savannah River facility of the Department of Energy (DOE). This site was chosen for an experimental project, conducted as part of DOE's integrated demonstrated program for environmental remediation. The project demonstrated a new in situ remediation technology that has the potential to reduce clean-up costs and time. Known as in situ air stripping, the new technology involves injection of air through underground horizontal wells to strip ground water and soils of volatile organics; the resulting diffused air is collected, and the hazardous chemicals are removed to the surface for further processing. This brochure briefly describes the use of the integrated demonstration approach, and in situ air stripping with horizontal wells as a viable new remediation method.

24C

Stabilization of Microorganisms for In Situ Degradation of Toxic Chemicals, Progress Report, Year Two.
Crawford, R. L. and Stormo, K., Idaho University, Moscow, ID, U.S. Department of Energy, Washington, DC, March 1991

NTIS Document Number: DE92-040792/XAB

Methods were developed to microencapsulate a petachlorophenol (PCP)-degrading Flavobacterium and a p-cresol (PCR)-degrading Pseudomonas within beads of 5-100 am diameter, and these entrapped cells were examined for their ability to mineralize PCP and PCR in the presence of subsurface soils and waters obtained from the University of Idaho (UI) Ground-Water Research Site (GRS). Matrices employed to make beads included alginate, agarose, polyurethane, agarose coated by polyurethane, and novel polyurethanes containing cross-linked sources of supplemental carbon and/or nitrogen sources. A low-pressure-nozzle apparatus was developed for the production of microspheres. Results showed that microencapsulated cells survived better and were catabolically more active than free cells in the presence of aquifer materials. Microcosm studies reported here confirmed that microbeads containing long-lived pollutant-degrading bacterial cells can be readily prepared in sizes that will travel through subsurface sand/gravel aquifer

matrixes. Microencapsulated bacteria at PCP concentrations up to 275 ppm and free cells at PCP concentrations <150 ppm can remain active for extended periods under simulated aquifer conditions. Periods of several months are certainly attainable. This should be sufficient time to effect significant environmental restoration through biodegradation of specific targeted pollutants.

25A

Surfactant Flooding Technology for In Situ Cleanup of Contaminated Soils and Aquifers—A Feasibility Study.
Porzucek, C., U.S. Department of Energy, Los Alamos National Laboratory, NM, November 1989

NTIS Document Number: DE90-003989/XAB

The process of in situ, surfactant-enhanced soil washing has been investigated to determine its usefulness and limitations. Previous work on this subject has been reviewed critically. Entrapment/displacement mechanisms of nonaqueous phase liquids (NAPLs) in porous media have been identified and are discussed. The effect of surfactant on each of these mechanisms has been investigated. A joint research project has been initiated with Howard University personnel to determine the effect of surfactant on contaminants that have adsorbed onto soil surfaces. Results of this research are necessary to more fully determine the limitations of in situ, surfactant-enhanced soil washing. However, based on field observations of NAPLs and modification of an existing mass-transfer-based model, it is apparent that in situ, surfactant-enhanced soil washing alone will not be a sufficient remedial action plan because it cannot displace enough contaminant to clean the soil to within the Environmental Protection Agency's guidelines of cleanliness. The process shows the most promise when it is used in conjunction with another remedial action plan such as biorestoration.

25B

Terra Vac In Situ Vacuum Extraction System: Applications Analysis Report.
Stinson, M., Foster Wheeler Enviresponse, Inc., Livingston, NJ, U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, Cincinnati, OH, July 1989

EPA Document Number: EPA/540/A5-89/003

NTIS Document Number: PB90-119744/XAB

The report analyzes the results from the Superfund Innovative Technology Evaluation Program's 56-day demonstration at the Valley Manufactured Product Company's site in Groveland, Massachusetts. Conclusions were reached concerning the technology's suitability for use in remediations involving both similar and different materials at other sites. Operational data and sampling and analysis information were monitored carefully to establish a database against which vendor's claims for the technology could be evaluated. Additional data on the technology's performance at other sites is also discussed. The conclusions from the results of the Groveland demonstration test and from other available data are: 1) the process can be used to remediate a site contaminated with VOCs; 2) the process can remove VOCs from soils with permeabilities as low as 10^{-5} cm/s; 3) the process operates well in all weather conditions; and 4) the process implementation costs can be as low as $20/ton, depending on various site-specific conditions.

25C

Treatability of Contaminated Ground Water and Aquifer Solids at "Town Gas" Sites, Using Photolytic Ozonation and Chemical In Situ Reclamation, Final Report.
Peyton, G. R.; LeFaivre, M. H.; and Smith, M. A., Illinois State Water Survey Division, Champaign, Aquatic Chemistry Section, Illinois Department of Energy and Natural Resources, Champaign, Hazardous Waste Research and Information Center, August 1990

NTIS Document Number: PB90-267253/XAB

The feasibility of cleaning up contaminated ground water and aquifer solids from so-called "town gas" sites using photolytic ozonation and chemical in situ aquifer reclamation (CISR) techniques was investigated in the laboratory. At the actual site, coal was thermally oxidized to produce methane for municipal distribution. The degradation left a coal which, if released into the ground, could contaminate ground water and aquifer solids with a number of organic substances, including aromatic hydrocarbons such as benzene, toluene, xylene (BTX), and polynuclear aromatic hydrocarbons (PAHs) at environmentally significant concentrations. A chemical in situ treatment method using persulfate as a source of free radicals destroyed organic contaminants that were adsorbed to the aquifer solids. PAHs were reduced by 34 percent after 12 days of treatment and by 52 percent after 40 days.

OTHER RESOURCE GUIDES

25D

Bioremediation Resource Guide.
U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Technology Innovation Office, Washington, DC, September 1993
(see abstract below)

EPA Document Number: EPA/542/B-93/004

26A

Physical/Chemical Treatment Technology Resource Guide.
U.S. Environmental Protection Agency, Office of Solid Waste And Emergency Response, Technology Innovation Office, Washington, DC, September 1994
(see abstract below)

EPA Document Number: EPA/542-B-94/008

26B

Soil Vapor Extraction (SVE) Treatment Technology Resource Guide.
U.S. Environmental Protection Agency, Office of Solid Waste And Emergency Response, Technology Innovation Office, Washington, DC, September 1994

EPA Document Number: EPA/542-B-94/007

These documents are intended to support decision-making by Regional and State Corrective Action permit writers, Remedial Project Managers (RPMs), On-Scene Coordinators, contractors, and others responsible for the evaluation of innovative treatment technologies. These guides direct managers of sites being remediated under RCRA, UST, and CERCLA to bioremediation, ground-water, physical/chemical, and soil vapor extraction treatment technology resource documents; databases; hotlines; and dockets, and identify regulatory mechanisms (e.g., Research Development and Demonstration Permits) that have the potential to ease the implementation of these technologies at hazardous waste sites. Collectively, the guides provide abstracts of over 300 guidance/workshop reports, overview/program documents, studies and demonstrations, and other resource guides, as well easy-to-use Resource Matrices that identify the technologies and contaminants discussed in each abstracted document.

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GROUND-WATER TREATMENT TECHNOLOGY RESOURCE MATRIX

Abstract Identification Code 8 (page #) A (abstract code)	Document Title[1] Document Ordering Number	TECHNOLOGY TYPE[2]			CONTAMINANTS[2]								Originating Organization/Author
					VOCs		Semi-VOCs						
		Vapor Extraction Air Stripping Air Sparging	Biological Treatment	Other Technologies	BTEX[3]	Other-VOCs	PAHs	Other Semi-VOCs	Pesticides	Organics[4]	Metals Inorganics[4]	Radioactive	
GUIDANCE/WORKSHOPS													
8A	Biotechnology Workgroup for Department of Defense Soil and Ground Water Decontamination Applications, Final Report for Period Ending March 1989 NTIS AD-A237 956/8/XAB		●			●		●			●		Life Systems, Inc., Naval Civil Engineering Lab.; Reuter
8B	NPL Construction Completion Definition at Bioremediation and Soil Vapor Extraction Sites Directive EPA/540/F-93/019, NTIS PB93-963327/XAB	●	●			●							EPA/OSWER
OVERVIEW													
8C	An Overview of Underground Storage Tank Remediation Options EPA/510/F-93/029	●	●	Pump and Treat	●	●	●	●	●	●	●	●	EPA/OSWER
8D	Bioremediation EPA/600/A-93/004, NTIS PB93-149193/XAB		●							●			EPA/Robert S. Kerr Lab, Nationall Center for Ground Water Research, Thomas, Ward, Raymond, Wilson, Loehr
9A	Critical Review of In Situ Bioremediation, Topical Report, January 1990 - March 1992 NTIS PB93-114247/XAB		●		●			●			●	●	Illinois University, North Dakota University, Gas Research Institute, DOE; Rittman, Valocchi, Seagren, Ray, Wrenn
9B	Evaluation of Ground-Water Extraction Remedies. Phase 2, Volume 1, Summary Report NTIS PB92-963346/XAB		●			●		●		●	●	●	EPA/OERR
9C	Fifth Forum on Innovative Hazardous Waste Treatment Technologies: Domestic and International EPA/540/R-94/503	●	●	Microfiltration Sorption Filtration Photochemical Oxidation	●	●	●	●	●	●	●		EPA/OSWER/TIO/ORD/RREL
9D	Fourth Forum on Innovative Hazardous Waste Treatment Technologies: Domestic and International, Technical Papers EPA/540/R-93/500		●	Chemical Oxidation Microfiltration		●		●		●	●	●	EPA/OSWER/TIO/ORD/RREL
10A	Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration EPA/540/R-93/080, NTIS PB93-963507/XAB												EPA/OSWER
10B	Innovative Treatment Technologies: Annual Status Report, Fifth Edition EPA/542/R-93/003, NTIS PB93-133387/XAB	●		Chemical Treatment, Dechlorination, In Situ Flushing, In Situ Vitrification, Solvent Extraction, Thermal Desorption				●					EPA/OSWER/TIO; Fiedler
10C	Innovative Treatment Technologies: Overview and Guide to Information Sources EPA/540/9-91/002, NTIS PB92-179001/XAB		●	In Situ Chemical Treatment, In Situ Flushing									EPA/OSWER/TIO; Quander, Kingscott
11A	In Situ Bioremediation of Contaminated Ground Water EPA540/S-92/003, NTIS PB92-224336/XAB		●	Electrokinetics		●		●		●	●	●	EPA/OSWER; Sims, Suflita, Russell
11B	In Situ Bioremediation of Ground Water and Geological Material: A Review of Technologies, Research Report EPA/600/R-93/124, NTIS PB93-215564/XAB	●	●		●	●	●	●		●			Dynamac Corp., EPA/Robert S. Kerr Lab; Norris, Hinchee, Brown, McCarty, Semprini
11C	In Situ Bioremediation of Ground Water, Summary Paper EPA/540/S-92/017, NTIS PB93-146850/XAB		●		●	●	●	●	●	●			EPA/Robert S. Kerr Lab
11D	In Situ Treatment of Contaminated Ground Water: An Inventory of Research and Field Demonstrations and Strategies for Improving Ground Water Remediation Technologies EPA/500/K-93/001, NTIS PB93-193720/XAB		●					●		●			EPA/OSWER/TIO, Steimle
12A	Superfund Innovative Technology Evaluation (SITE) Program: Innovation Making a Difference												EPA/ORD/RREL

12A	Superfund Innovative Technology Evaluation (SITE) Difference EPA/540/F-94/505												
12B	Superfund Innovative Technology Evaluation Program: Technology Profiles, Sixth Edition EPA/540/R-93/526, NTIS PB93-163053/XAB	●	●	Electrokinetics, Multiple Technologies	●	●	●	●	●	●	●	●	EPA/ORD/RREL
12C	Surfactants and Subsurface Remediation, Journal Article: Published in *Environmental Science Technology*, v26 n12, pg. 2324-2330, 1992 EPA/600/J-93/003, NTIS PB93-149854/XAB		●	Surfactants, Chemical Treatment			●	●					EPA/Robert S. Kerr Lab, Oklahoma University Research Institute; West, Harwell
12D	Synopses of Federal Demonstrations of Innovative Site Remediation Technologies EPA/542/B-93/009, NTIS PB94-151065/XAB	●	●	Electrokinetics, Multiple Technologies	●	●	●	●	●	●	●	●	EPA/OSWER/TIO
13A	TCE Removal from Contaminated Soil and Ground Water EPA/540/S-92/002, NTIS PB92-224104/XAB	●	●	Carbon Adsorption In-well Aeration		●							EPA/ORD/OSWER/TIO, Robert S Kerr Environmental Lab; Russell, Matthews, Sewell
13B	Technologies to Remediate Hazardous Waste Sites DE90-011946/XAB	●	●							●	●	●	Battelle Pacific Northwest Labs, DOE, Falco
13C	Technology Assessment of Soil Vapor Extraction and Air Sparging EPA/600/R-92/173, NTIS PB93-100154/XAB	●	●		●	●							CDM, Inc., EPA/ORD/RREL; Loden
13D	Technology Catalogue, First Edition DOE/EM-0138P, NTIS DE94-008866/XAB	●	●	Dynamic Underground Stripping		●				●			DOE/OEM/OTD
14A	VOCs in Arid Soils: Technology Summary DOE/EM-0136P, NTIS DE94-008864/XAB	●	●			●					●	●	DOE/OEM/OTD

Documents Focusing On Test Design

14B	Combining Treatability Studies and Site Characterization for Rational Design in Situ Bioremediation Using Nitrate as an Electron Acceptor EPA/600/A-93/172, NTIS PB93-221901/XAB		●		●								EPA/Robert S. Kerr Lab, ManTech Environmental Technology, Inc., Dynamac Corp.; Hutchins, Kampbell, Cook, Pfeifer, Cosby
14C	Effects of Ground Water Chemistry on Co-Metabolism of Chlorinated Solvents by Methanotrophic Bacteria NTIS DE91-014223/XAB		●			●		●					DOE/Oak Ridge National Lab; Palumbo, Strandberg
14D	Experimental Evaluation of the Mathematical Model for In Situ Aquifer Restoration Processes EPA/600/A-93/147, NTIS PB93-212363/XAB		●			●				●			EPA/Robert S. Kerr Lab, Pennsylvania State University; Short, Yeh
15A	In Situ Bioremediation of Spills from Underground Storage Tanks: New Approaches for Site Characterization, Project Design, and Evaluation of Performance EPA/600/S2-89/042, NTIS PB89-219976/XAB		●		●								EPA/Robert S. Kerr Environmental Research Lab; Wilkson, Lowell, Michalowski, Vandergrift, Callaway
15B	In Situ Redox Manipulation: Enhancement of Contaminant Destruction and Immobilization NTIS DE93-007877/XAB			Chemical Treatment		●				●	●	●	Battelle Pacific Northwest Labs, DOE, Fruchter
15C	Methodologies for Evaluating In Situ Bioremediation of Chlorinated Solvents, Research Report 21, August 19, 1989 - June 19, 1991 EPA/600/R-92/042, NTIS PB92-146943/XAB		●			●		●		●	●		Stanford University, EPA/Robert S Kerr Lab; Semprini, Grbic-Galic, McCarty, Roberts
15D	Novel Closed Loop Air Stripping Process for VOC Removal from Contaminated Water, Final Report NTIS PB92-218247/XAB	●				●							Minnesota University, U.S. Geological Survey; Shownick, Sontag, Semmens
16A	Office of Technology Development Integrated Program for Development of In Situ Remediation Technologies NTIS DE93-001312/XAB		●	In Situ Treatment, In Situ Containment, Electrokinetics		●		●		●	●	●	Battelle Pacific Northwest Labs, DOE, Peterson
16B	Preliminary Evaluation of Selected In Situ Remediation Technologies for Volatile Organic Compounds Contamination at Arid Sites NTIS DE93-002182/XAB			Multiple Technologies		●							Battelle Pacific Northwest Labs, DOE Lenhard, Gerber, Amonette
16C	*Savannah River*: Horizontal Wells for In Situ Remediation of Ground Water and Soils NTIS DE89-010456/XAB	●				●							DuPont Co., DOE/Savannah River Lab, Sirrine Environmental Consultants; Kaback, Looney, Corey Wright, Steele
16D	*Savannah River*: In Situ Remediation System for Contaminated Ground Water, Patent Application NTIS DE91-017331/XAB					●							DOE/Savannah River Lab, Corey Looney, Kaback

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GROUND-WATER TREATMENT TECHNOLOGY RESOURCE MATRIX

Abstract Identification Code (page #) A (abstract code)	Document Title[1] Document Ordering Number	TECHNOLOGY TYPE											Originating Organization/Author
		Vapor Extraction Air Stripping Air Sparging	Biological Treatment	Other Technologies	VOCs: BTEX[3]	VOCs: Other-VOCs	Semi-VOCs: PAHs	Semi-VOCs: Other Semi-VOCs	Pesticides	Organics[4]	Metals/ Inorganics[4]	Radioactive	
17A	*Savannah River:* Test Plan for In Situ Bioremediation Demonstration of the Savannah River Integrated Demonstration Project, DOE/OTD TTP No. S0566-01 NTIS DE92-013973/XAB		●			●							Westinghouse Savannah River Co., DOE; Hazen
17B	Solvent Extraction for Remediation of Coal Tar Sites, Final Report NTIS PB93-118347/XAB			Chemical Treatment, Solvent Extraction		●	●	●		●			Carnegie-Mellon University, U.S. Geological Survey; Lulley, Dzombak, Peters, Ali, [illegible]
Documents Focusing On Study Results													
17C	Applied Geologic, Microbiological, and Engineering Constraints of In Situ BTEX Bioremediation, Journal Article: Published in *Remediation*, v3 n1, pg. 83-110, Winter 1992-93 EPA/600/J-92/450, NTIS PB93-141513/XAB		●	Microfiltration Chemical Treatment Filter Pressing Dewatering	●	●				●	●	●	EPA/Robert S. Kerr Lab, American Environmental Consultants, Inc.; Kennedy, Hutchins
18A	A Process for Contaminant Removal and Waste Volume Reduction to Remediate Groundwater Containing Certain Radionuclides, Toxic Metals, and Organics, Final Report DOE/CH-9201			Multiple Technologies		●							Argonne National Lab., Chemical Technology Division; Buckley, Kelley, Vijayan, Wong
18B	Characteristics of the Volatile Organic Compounds -- Arid Integrated Demonstration Site NTIS DE92-003682/XAB			Pump and Treat						●	●		Battelle Pacific Northwest Labs, DOE; Last, Lenhard, Bjornstad, Evans, Roberson
18C	Chemical Enhancements to Pump-and-Treat Remediation EPA/540/S-92/001, NTIS PB92-189074/XAB												EPA/ORD/OSWER/TIO, Robert S. Kerr Env. Lab; Palmer and Fish
18D	Comparison of Bioventing and Air Sparging for In Situ Bioremediation of Fuels EPA/600/A-93/178, NTIS PB93-221968/XAB	●	●		●								EPA/Robert S. Kerr Lab, Solar Universal Technologies, Inc., Coast Guard Civil Engineering Unit; Kampbell, Griffin, Blaha
19A	E. I. DuPont De Nemours & Company/Oberlin Filter Company Microfiltration Technology: Applications Analysis Report EPA/540/A5-90/007, NTIS PB92-119023/XAB			Microfiltration							●		EPA/ORD/RREL
19B	Enhanced Bioremediation Utilizing Hydrogen Peroxide as a Supplemental Source of Oxygen: A Laboratory and Field Study EPA/600/S-29/008, NTIS PB90-183436/XAB		●		●								EPA/Robert S. Kerr Lab
19C	Experimental Examination of Integrated Soil Vapor Extraction Techniques, Journal Article: Published in *Proceedings of the Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection, and Restoration*, pg. 441-462, November 1992 EPA/600/J-92/260, NTIS PB93-131738/XAB	●			●	●			●				Oregon Graduate Institute of Science and Technology, EPA/ORD/RREL; Johnson, [illegible], Perrott, Chen
19D	Feasibility of Biodegradation of Tetrachloroethylene in Contaminated Aquifers, Final Report NTIS PB91-169778/XAB		●			●		●					Cambridge Analytical Associates, Inc., National Science Foundation; Fogel
20A	Influence of Microbial Transport Processes on "In Situ" Biodegradation of Ground Water Contaminants, Technical Progress Report, Final NTIS PB91-234732/XAB		●					●					Montana State University, U.S. Geological Survey; Cunningham, Characklis
20B	In Situ Biodegradation Treatment EPA/540/S-94/502			In Situ Biodegradation						●			EPA/OERR/ORD
20C	In Situ Bioremediation of Hanford Ground Water NTIS DE92-012360/XAB		●			●					●	●	Battelle Pacific Northwest Labs, DOE; Skeen, Roberson, Workman, Petersen, Shouche
21A	In Situ Generation of Oxygen By Electrolysis and the Electrochemical Effects on Microorganisms' Population, Final Report, September 19, 1990 - November 19, 1991 NTIS AD-A252358/7/XAB		●	In Situ Electrolysis						●			Battelle Columbus Labs, Naval Civil Engineering Lab; Han, Wyza, Ollenbuttel
21B	In Situ Steam Extraction Treatment, Engineering Bulletin EPA/540/2-91/005, NTIS PB91-228064/XAB	●		Steam Extraction		●		●		●			SAIC, EPA/OSWER/OERR

21B	In Situ Steam Extraction Remediation, Engineering Cost ... EPA/540/2-91/005, NTIS PB91 228064/XAB	●		Steam Extraction		●		●		●			
21C	Laboratory Evaluation of the In Situ Chemical Treatment Approach for Remediation of Contaminated Soils and Ground Water NTIS DE93-006901/XAB			Chemical Treatment							●	●	Westinghouse Hanford Co., DOE; Thorton, Jurgensmeier, Baechler
21D	Performance Evaluation of a Ground Water and Soil Gas Remedial Action NTIS DE90-017659/XAB		●	Ground-Water Extraction		●							DOE/Argonne National Lab; Hansen, Hartnett
22A	perox-pure ™ Chemical Oxidation Technology Peroxidation Systems, Inc.: Applications Analysis Report EPA/540/AR-93/501, NTIS PB94-130325/XAB			Chemical Oxidation		●				●			EPA/ORD/RREL
22B	Reductive Dehalogenation: A Subsurface Bioremediation Process, Journal Article: Published in *Remediation*, Winter 1990-1991 EPA/600/J-92/258, NTIS PB91-144873/XAB		●			●		●		●			EPA/Robert S. Kerr Lab; Sims, Sulita, Russell
22C	Removal of Radionuclides by Electrokinetic Soil Processing, Journal Article: Published in *Journal of the National Technical Association*, Spring 1993 EPA/600/J-93/298, NTIS PB93-222876/XAB			Electrokinetics							●	●	EPA/ORD/RREL; Parker
22D	Retrospective Performance Evaluation of In Situ Bioremediation: Site Characterization EPA/600/A-93/173, NTIS PB93-221919/XAB		●		●	●	●	●		●			EPA/Robert S. Kerr Lab; Wilson, Kampbell
23A	*Savannah River:* Field Demonstration of In Situ Air Stripping Using Horizontal Wells NTIS DE92-009663	●				●							Westinghouse Savannah River Co., DOE; Looney, Kaback
23B	*Savannah River:* Full-Scale Field Test of the In Situ Air Stripping Process at the Savannah River Integrated Demonstration Test Site NTIS DE92-009749/XAB	●				●		●					Westinghouse Savannah River Co., DOE; Looney, Hazen, Kaback, Eddy
23C	*Savannah River:* Ground Water and Soil Remediation: In Situ Air Stripping Using Horizontal Wells NTIS DE92-009908/XAB	●			●	●				●			Westinghouse Savannah River Co., DOE; Kaback, Looney, Eddy Hazen
24A	*Savannah River:* Immunological Techniques as Tools to Characterize the Subsurface Microbial Community at a Trichloroethylene Contaminated Site NTIS DE93-007443/XAB		●			●							Westinghouse Savannah River Co., DOE; Fliermans, Dougherty, Franck, McKinzey, Hazen
24B	*Savannah River:* Savannah River Integrated Demonstration Program NTIS DE92-009587/XAB	●		Unspecified		●				●			Westinghouse Savannah River Co., DOE
24C	Stabilization of Microorganisms for In Situ Degradation of Toxic Chemicals, Progress Report, Year Two NTIS DE93-0407920/XAB		●					●					Idaho University, DOE; Crawford, Sterne
25A	Surfactant Flooding Technology for In Situ Cleanup of Contaminated Soils and Aquifers, A Feasibility Study NTIS DE90-003998/XAB		●	Surfactants, Chemical Treatment						●			DOE/Los Alamos National Lab; Porzuczek
25B	Terra Vac In Situ Vacuum Extraction Systems: Applications Analysis Report EPA/540/AR-93/503, NTIS PB94-130744/XAB	●				●							EPA/ORD/RREL, Foster Wheeler Environmental, Inc.; Simon
25C	Treatability of Contaminated Groundwater and Aquifer Solids at "Tom's Site" Using Photolytic Oxidation and Chemical In Situ Reclamation, Final Report NTIS PB93-[illegible]/XAB			Chemical Treatment	●	●	●	●		●			Illinois Department of Energy and Natural Resources; Peyton, LeFaivre, Smith
25D	Bioremediation Resource Guide EPA/542-B-94/004	Bioremediation											EPA/OSWER/TIO
26A	Physical/Chemical Treatment Technology Resource Guide EPA/542-B-94/008	Soil Washing/Flushing, Solvent Extraction, Thermal Desorption, Chemical Dehalogenation											EPA/OSWER/TIO
26B	Soil Vapor Extraction Treatment Technology Resource Guide EPA/542-B-94/007	Soil Vapor Extraction											EPA/OSWER/TIO

Note 1: This matrix provides representative examples of ground water treatment technology resource documents. It is not all inclusive. Those seeking other information may wish to contact the hotlines, dockets, or other sources listed on pages 4-6 of this document.

Note 2: The information in this matrix is derived from NTIS abstracts and is only as detailed as the NTIS abstracts.

Note 3: BTEX is included as a separate contaminant category at the request of the Office of Underground Storage Tanks.

Note 4: An entry under the Organics and Metals/Inorganics columns indicates a general reference to these contaminants. Further research into the document content may be necessary to determine precisely which contaminants are discussed.

Note 5: The heading, Studies and Demonstrations, is divided into the following two sub-headings: Documents Focusing on Test Designs and Documents Focusing on Study Results. Documents included in the Study Results subsections may comprehensively cover the study process from design through completion.

Note 6: The Resource Guides direct readers to technical documents but do not explicitly identify contaminants.