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SITE

SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION
PROGRAM

Technology Profiles
Seventh Edition

Risk Reduction Engineering Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

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DISCLAIMER

The development of this document was funded by the U.S. Environmental Protection Agency (EPA) under Contract No. 68–C0–0047, Work Assignment No. 0-58, to PRC Environmental Management, Inc. The document was subjected to the Agency's administrative and peer review and was approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use at any particular hazardous waste site.

FOREWORD

The U.S. Environmental Protection Agency's (EPA) Risk Reduction Engineering Laboratory (RREL) is responsible for planning, implementing, and managing research, development, and demonstration programs that provide the scientific and engineering basis for EPA policies, programs, and regulations concerning drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities.

The Superfund Innovative Technology Evaluation (SITE) Program, now in its ninth year, is an integral part of EPA's research into alternative cleanup methods for hazardous waste sites around the Nation. Under the SITE Program, EPA enters into cooperative agreements with technology developers. These developers research and refine their innovative technologies at bench- or pilot-scale and may demonstrate them, with support from EPA, at hazardous waste sites. The SITE Program demonstrates technologies that are ready for commercialization. EPA collects and publishes engineering, performance, and cost data to aid in future decision-making for hazardous waste site remediation.

The successful implementation of innovative technologies requires a team approach. SITE Program staff work closely with EPA's regional offices, other federal agencies, state and local governments, technology developers, the Environmental Monitoring Systems Laboratory (EMSL), the Superfund Technology Assistance Response Team (START), and the Office of Solid Waste and Emergency Response (OSWER) to provide technology demonstrations and to disseminate information. The SITE Program also uses EPA research facilities, such as the Test and Evaluation (T&E) Facility and the Center Hill Facility in Cincinnati, Ohio, to evaluate innovative technologies.

This Technology Profiles document is a product of the SITE Program. It provides a vital communication link between the researcher and the user community and is intended for environmental decision-makers and other individuals involved in hazardous waste site cleanup. This is the seventh edition of the Technology Profiles document. Distribution of the Technology Profiles has increased steadily as the SITE Program has grown. About 1,000 copies of the first edition were distributed in 1988; over 25,000 copies of the sixth edition, published in November 1993, have been distributed.

This document profiles 198 demonstration, emerging, and monitoring and measurement technologies being evaluated under the SITE Program. Each profile describes the technology; discusses its applicability to various wastes; discusses its development or demonstration status and demonstration results, if available; and provides demonstration and technology contacts.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

ABSTRACT

The Superfund Innovative Technology Evaluation (SITE) Program evaluates new and promising treatment and monitoring and measurement technologies for cleanup of hazardous waste sites. The program was created to encourage the development and routine use of innovative treatment technologies. As a result, the SITE Program provides environmental decision-makers with data on new, viable treatment technologies that may have performance or cost advantages compared to traditional treatment technologies.

This document, prepared between June 1994 and October 1994, is intended as a reference guide for those interested in technologies under the SITE Demonstration, Emerging Technology, and Monitoring and Measurement Technologies Programs. The two-page profiles are organized into two sections for each program, completed and ongoing projects, and are presented in alphabetical order by developer name. Reference tables for SITE Program participants precede the sections and contain EPA and developer contacts. Inquiries about a SITE technology evaluation or the SITE Program should be directed to the EPA project manager; inquiries on the technology process should be directed to the technology developer contacts.

Each technology profile contains (1) a technology developer and process name, (2) a technology description, including a schematic diagram or photograph of the process, (3) a discussion of waste applicability, (4) a project status report, and (5) EPA project manager and technology developer contacts. The profiles also include summaries of demonstration results if available. The technology description and waste applicability sections are written by the developer. EPA prepares the status and demonstration results sections.

An Applicability Index is also included in the back of this document. The index is organized by the following media: (1) Air/Gas, (2) Fine Solids, (3) Groundwater, (4) Liquid, (5) Mine Tailings, (6) Mixed Waste, (7) Oily Waste, (8) Other Media, (9) Sediment, (10) Sludge, (11) Soil, (12) Wastewater/Leachate, and (13) Water.

The following waste categories are represented in the index: (1) Aromatic Volatile Organic Compounds (VOC), (2) Cyanide, (3) Diesel, (4) Dioxins, (5) Explosives, (6) Furans, (7) Gasoline, (8) Halogenated VOCs, (9) Heavy Metals, (10) Heavy Minerals, (11) Herbicides, (12) Inorganic Elements, (13) Metals, (14) Mixed Waste, (15) Organics, (16) Other Wastes, (17) Particulates, (18) Polynuclear Aromatic Hydrocarbons, (19) Polychlorinated Biphenyls, (20) Pesticides, (21) Petroleum Hydrocarbons, (22) Radionuclides, (23) Semivolatile Organic Compounds (SVOC), (24) Uranium, (25) Volatile Inorganics, and (26) VOCs.

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SITE PROGRAM DESCRIPTION

The U.S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) Program, now in its ninth year, encourages the development and implementation of (1) innovative treatment technologies for hazardous waste site remediation, and (2) monitoring and measurement technologies for evaluating the nature and extent of hazardous waste site contamination.

The SITE Program was established by EPA's Office of Solid Waste and Emergency Response (OSWER) and the Office of Research and Development (ORD) in response to the 1986 Superfund Amendments and Reauthorization Act (SARA), which recognized a need for an "Alternative or Innovative Treatment Technology Research and Demonstration Program." The SITE Program is administered by ORD's Risk Reduction Engineering Laboratory (RREL), headquartered in Cincinnati, Ohio.

The SITE Program includes the following component programs:

- **Demonstration Program** – Conducts and evaluates demonstrations of promising innovative technologies to provide reliable performance, cost, and applicability information for site cleanup decision–making

- **Emerging Technology Program** – Provides funding to developers to continue research efforts from the bench– and pilot–scale levels to promote the development of innovative technologies

- **Monitoring and Measurement Technologies Program** – Develops technologies that detect, monitor, and measure hazardous and toxic substances to provide better, faster, and more cost–effective methods for producing real–time data during site characterization and remediation

- **Technology Transfer Program** – Disseminates technical information on innovative technologies to remove impediments for using alternative technologies

This Technology Profiles document, a product of the Technology Transfer Program, describes completed and ongoing projects in the Demonstration, Emerging Technology, and Monitoring and Measurement Technologies Programs. Figure 1 depicts the process of technology development from initial concept to commercial use and shows the relationship among the programs.

In the Demonstration Program, the technology is field–tested on hazardous waste materials. Engineering and cost data are gathered on the innovative technology so that potential users can assess the technology's applicability to a particular site. Data collected during the field demonstration are used to assess the performance of the technology, the potential need for pre– and post–processing of the waste, applicable types of wastes and waste matrices, potential operating problems, and approximate capital and operating costs.

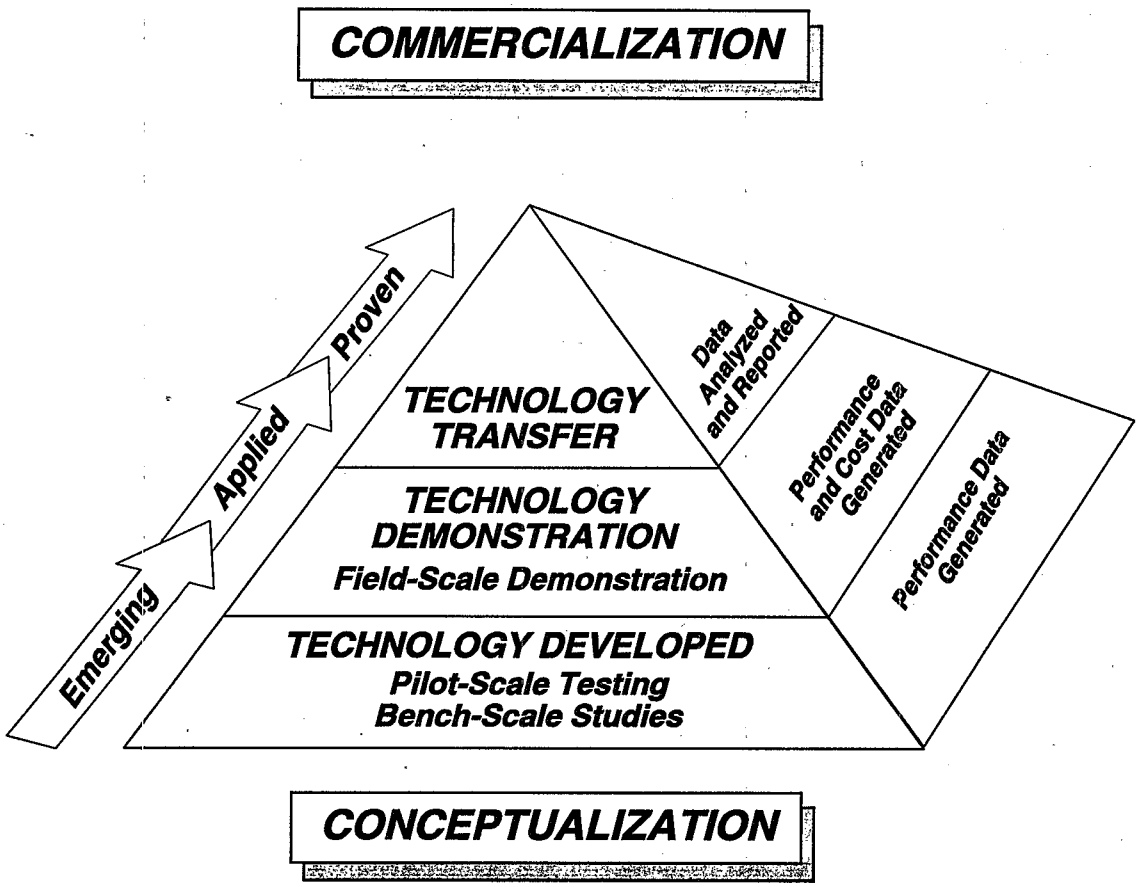

Figure 1: Development of Innovative Technologies

At the conclusion of a SITE demonstration, EPA prepares an Innovative Technology Evaluation Report (ITER), Technology Capsule, and Demonstration Bulletin. These reports evaluate all available information on the technology and analyze its overall applicability to other site characteristics, waste types, and waste matrices. Testing procedures, performance and cost data, and quality assurance and quality control standards are also presented. ITERs, Technology Capsules, Demonstration Bulletins, other demonstration documents, and videotapes are distributed by EPA to provide reliable technical data for environmental decision-making and to promote the technology's commercial use.

The Demonstration Program currently has 99 developers providing 111 demonstrations. Of these projects, 71 have completed demonstrations and 40 are ongoing. The projects are divided into the following categories: thermal destruction (12), biological degradation (18), physical/chemical treatment (47), solidification/stabilization (9), physical/chemical radioactive waste treatment (2), physical/chemical thermal desorption (18), materials handling (3), and other (2). Several technologies combine these treatment categories. Figure 2 shows the breakdown of technologies in the Demonstration Program.

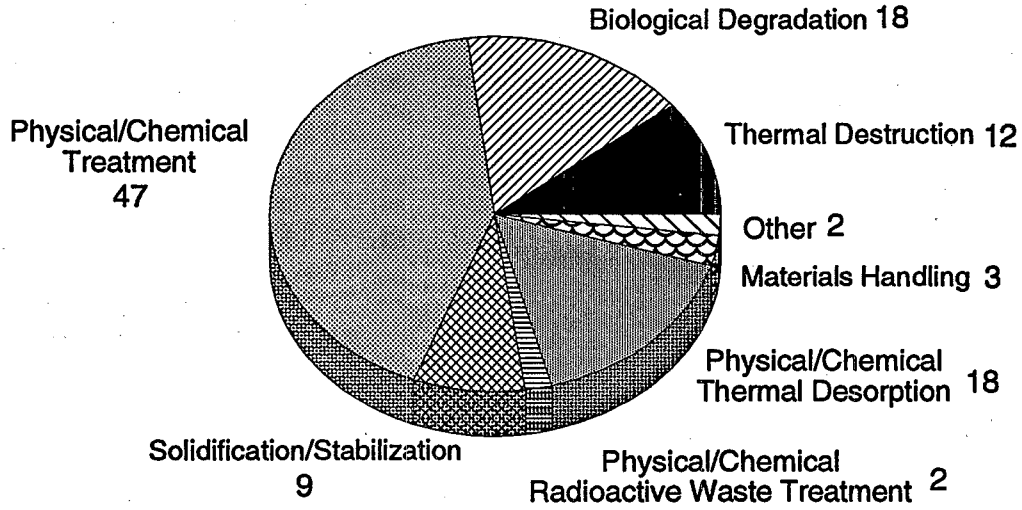

Figure 2: Innovative Technologies in the Demonstration Program

Under the Emerging Technology Program, EPA provides technical and financial support to developers for bench– and pilot–scale testing and evaluation of innovative technologies that are at a minimum proven on the conceptual and bench-scale levels. The program provides an opportunity for a private developer to research and develop a technology for field application and possible evaluation under the Demonstration Program. A technology's performance is documented in a final report, journal article, project summary, and bulletin.

EPA has provided technical and financial support to 72 projects in the Emerging Technology Program. Of these projects, 39 are completed, 32 are ongoing in the program, and one has exited the program. Fifteen Emerging Technology Program projects are participating in the Demonstration Program. The 72 technologies are divided into the following categories: thermal destruction (9), physical/chemical treatment (39), biological degradation (17), solidification/stabilization (2), and materials handling (5). Figure 3 displays the breakdown of technologies in the Emerging Technology Program.

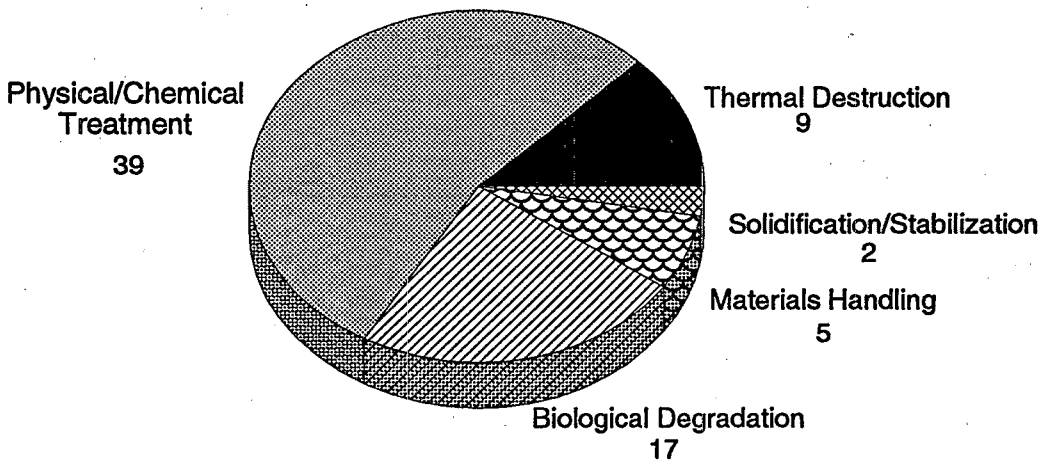

Figure 3: Innovative Technologies in the Emerging Technology Program

The Monitoring and Measurement Technologies Program's (MMTP) goal is to assess innovative and alternative monitoring, measurement, and site characterization technologies. During fiscal year 1994, five technologies were demonstrated. Additionally, the MMTP plans five demonstrations, each evaluating one or more monitoring and measurement technologies, in fiscal year 1995. To date, 98 technology demonstrations have been completed under the SITE Program (71 in the Demonstration Program and 27 in the MMTP); many reports have been published and others are in various stages of completion.

In the Technology Transfer Program, technical information on innovative technologies in the Demonstration Program, Emerging Technology Program, and MMTP is disseminated through various activities. These activities increase the awareness and promote the use of innovative technologies for assessment and remediation at Superfund sites. The goal of technology transfer activities is to promote communication among individuals requiring up-to-date technical information.

The Technology Transfer Program reaches the environmental community through many media, including:

- Program-specific regional, state, and industry brochures
- On-site Visitors' Days during SITE Demonstrations
- Demonstration videotapes
- Project-specific fact sheets to comply with site community relations plans
- ITERs, Demonstration Bulletins, Technology Capsules, Project Summaries
- The SITE Exhibit, displayed nationwide at conferences
- Networking through forums, associations, regions, and states
- Technical assistance to regions, states, and remediation cleanup contractors

SITE information is available through the following on-line information clearinghouses:

Alternative Treatment Technology Information Center (ATTIC)
System operator: 703-908-2137 or 908-321-6677

Vendor Information System for Innovative Treatment Technologies (VISITT)
Hotline: 800-245-4505 or 703-883-8448

Cleanup Information Bulletin Board System (CLU-IN)
Help Desk: 301-589-8368; Modem: 301-589-8366

Technical reports may be obtained by completing the document order form at the back of this document or calling the Center for Environmental Research Information (CERI) in Cincinnati, Ohio. Additional SITE documents become available throughout the year. To find out about newly published documents or to be placed on the SITE mailing list, call 513-569-7562 or write to:

CERI/ORD Publications
26 West Martin Luther King Drive (G72)
Cincinnati, OH 45268

SITE PROGRAM CONTACTS

The SITE Program is administered by EPA's Office of Research and Development (ORD), specifically the Risk Reduction Engineering Laboratory (RREL). For further information on the SITE Program or its component programs contact:

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Demonstration Program

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702-798-2232
Fax: 702-798-2261

DEMONSTRATION PROGRAM

The SITE Demonstration Program develops reliable engineering, performance, and cost data on innovative, alternative technologies so that potential users can evaluate a technology's applicability for a specific waste site. Demonstrations are conducted at hazardous waste sites, such as National Priorities List (NPL) sites, non–NPL sites, and state sites, or under conditions that simulate actual hazardous wastes and site conditions.

Technologies are selected for the SITE Demonstration Program through annual requests for proposals (RFP). EPA reviews proposals to determine the technologies with promise for use at hazardous waste sites. Several technologies have entered the program from current Superfund projects, in which innovative techniques of broad interest were identified for evaluation under the program. In addition, several Emerging Technology projects have moved to the Demonstration Program. To date, nine solicitations have been completed — SITE 001 in 1986 through SITE 009 in 1994. The RFP for SITE 010 is expected to be issued in January 1995.

The SITE demonstration process typically consists of five steps: (1) matching an innovative technology with an appropriate site; (2) preparing a Demonstration Plan including the test plan, sampling and analysis plan, quality assurance project plan, and health and safety plan; (3) performing community relations activities; (4) conducting the demonstration (ranging in length from days to months); and (5) documenting results in an Innovative Technology Evaluation Report, a Technology Capsule, other demonstration documents, and a demonstration videotape.

Cooperative agreements between EPA and the developer set forth responsibilities for conducting the demonstration and evaluating the technology. Developers are responsible for operating their innovative systems at a selected site, and are expected to pay the costs to transport equipment to the site, operate the equipment on site during the demonstration, and remove the equipment from the site. EPA is responsible for project planning, waste collection and pretreatment (if needed), sampling and analysis, quality assurance and quality control, preparing reports, and disseminating information.

Demonstration data are used to assess the technology's performance, the potential need for pre– and post–processing of the waste, applicable types of wastes and media, potential operating problems, and the approximate capital and operating costs. Demonstration data can also provide insight into long–term operating and maintenance costs and long–term risks.

The Demonstration Program currently includes 99 developers and 111 projects. These projects are organized into two sections, completed projects and ongoing projects. The completed projects are presented in alphabetical order by developer name in Table 1 and in the profiles that follow; the ongoing projects are presented in Table 2 and in the profiles that follow.

TABLE 1

Completed SITE Demonstration Program Projects as of October 1994

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Accutech Remedial Systems, Inc., Keyport, NJ (005)* *Demonstration Date:* July - August 1992	Pneumatic Fracturing Extraction℠ and Catalytic Oxidation/New Jersey Environmental Cleanup Responsibility Act Site in Hillsborough, NJ	John Liskowitz 908-739-6444	Uwe Frank 908-321-6626	Soil, Rock	Not Applicable	Halogenated and Nonhalogenated VOCs and SVOCs
Advanced Remediation Mixing, Inc. (formerly Chemfix Technologies/ CeTech Resources), Kenner, LA (002) *Demonstration Date:* March 1989	Solidification and Stabilization/ Portable Equipment Salvage Company Site in Clackamas, OR	Sam Pizzitola 504-461-0466	Edwin Barth 513-569-7669	Soil, Sludge, Solids, Ash, Electroplating Wastes	Heavy Metals	High Molecular Weight Organics
American Combustion, Inc., Norcross, GA (001) *Demonstration Date:* November 1987 - January 1988	PYRETRON® Thermal Destruction/EPA's Incineration Research Facility in Jefferson, AR using soil from Stringfellow Acid Pit Superfund Site in Glen Avon, CA	Gregory Gitman 404-564-4180	Laurel Staley 513-569-7863	Soil, Sludge, Solid Waste	Not Applicable	Nonspecific Organics
AWD Technologies, Inc., San Francisco, CA (004) *Demonstration Date:* September 1990	Integrated Vapor Extraction and Steam Vacuum Stripping/San Fernando Valley Groundwater Basin Superfund Site in Burbank, CA	David Bluestein 415-227-0822	Gordon Evans 513-569-7684	Groundwater, Soil	Not Applicable	VOCs
Babcock & Wilcox Co.,** Alliance, OH (006) *Demonstration Date:* November 1991	Cyclone Furnace/Developer's Facility in Alliance, OH	Dorothy Haidet 216-829-7395	Laurel Staley 513-569-7863	Solids, Soil, Sludge	Nonspecific, Low-Level Radionuclides	Nonspecific Organics
Bergmann USA, Gallatin, TN (007) *Demonstration Date:* May 1992	Soil and Sediment Washing/ Saginaw Bay Confined Disposal Facility in Saginaw, MI	Richard Traver 615-230-2217	Jack Hubbard 513-569-7507	Soil, Sediment	Heavy Metals	PCBs, Nonspecific Organics

* Solicitation Number
** From Emerging Technology Program

TABLE 1 (continued)

Completed SITE Demonstration Program Projects as of October 1994

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Berkeley Environmental Restoration Center (formerly Udell Technologies, Inc.), Berkeley, CA (005) *Demonstration Date:* December 1993	In Situ Steam Enhanced Extraction Process/Lawrence Livermore National Laboratory in Altamont Hills, CA	Kent Udell 510-642-2928 Steve Collins 510-643-1300	Paul dePercin 513-569-7797	Soil, Groundwater	Not Applicable	VOCs and SVOCs, Hydrocarbons, Solvents
Billings and Associates, Inc., Albuquerque, NM (007) *Demonstration Date:* March 1993 - May 1994	Subsurface Volatilization and Ventilation System (SVVS®)/ Site in Buchanan, Michigan	Gale Billings 505-345-1116 Don Brenneman 713-575-4693	Paul dePercin 513-569-7797	Soil, Sludge, Groundwater	Not Applicable	BTEX, VOCs, SVOCs
BioGenesis Enterprises, Inc., Springfield, VA (005) *Demonstration Date:* November 1992	BioGenesis℠ Soil and Sediment Washing Processes/Refinery Site in Minnesota	Thomas Rougeux 703-913-9700	Annette Gatchett 513-569-7697	Soil	Not Applicable	Volatile and Nonvolatile Hydrocarbons, PCBs
Bio-Rem, Inc., Butler, IN (006) *Demonstration Date:* May 1992 - June 1993	Augmented In Situ Subsurface Bioremediation Process/ Williams AFB in Phoenix, AZ	David Mann 219-868-5823 800-428-4626	Teri Richardson 513-569-7949	Soil, Water	Not Applicable	Hydrocarbons, Halogenated Hydrocarbons, and Chlorinated Compounds
BioTrol, Inc., Eden Prairie, MN (003) *Demonstration Date:* July - September 1989	Biological Aqueous Treatment System/MacGillis and Gibbs Superfund Site in New Brighton, MN	Sandra Clifford 612-942-8032	Mary Stinson 908-321-6683	Liquid Waste, Groundwater	Nitrates	Chlorinated and Nonchlorinated Hydrocarbons, Pesticides
BioTrol, Inc., Eden Prairie, MN (003) *Demonstration Date:* September - October 1989	Soil Washing System/MacGillis and Gibbs Superfund Site in New Brighton, MN	Sandra Clifford 612-942-8032	Mary Stinson 908-321-6683	Soil	Metals	High Molecular Weight Organics, PAHs, PCP, PCBs, Pesticides
Brice Environmental Services Corporation, Fairbanks, AK (006) *Demonstration Date:* September 1992	Soil Washing Plant/Alaskan Battery Enterprises Superfund Site in Fairbanks, AK	Craig Jones 907-452-2512	Hugh Masters 908-321-6678	Soil	Radioactive and Heavy Metals	Not Applicable

TABLE 1 (continued)

Completed SITE Demonstration Program Projects as of October 1994

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Canonie Environmental Services Corporation, Porter, IN (006) *Demonstration Date:* September 1992	Low Temperature Thermal Aeration (LTTA®)/Pesticide Site in Phoenix, AZ	Thomas Froman 219-926-8651	Paul dePercin 513-569-7797	Soil, Sludge, Sediment	Not Applicable	VOCs, SVOCs, OCPs, OPPs, TPHs
CF Systems Corporation, Woburn, MA (002) *Demonstration Date:* September 1988	Liquified Gas Solvent Extraction (LG-SX) Technology/New Bedford Harbor Superfund Site in New Bedford, MA	Chris Shallice 617-937-0800	Mark Meckes 513-569-7348	Soil, Sludge, Wastewater	Not Applicable	VOCs, SVOCs, PAHs, PCBs, Dioxins, and Pentachlorophenol
COGNIS, Inc.,** Santa Rosa, CA (009)/(E05) *Demonstration Date:* August 1994	Chemical Treatment/Twin Cities Army Ammunition Plant in New Brighton, MN	Bill Fristad 707-576-6235	Michael Royer 908-321-6633	Soil, Sludge, Sediment	Lead, Heavy Metals	Not Applicable
Dehydro-Tech Corporation, East Hanover, NJ (004) *Demonstration Date:* August 1991	Carver-Greenfield Process® for Solvent Extraction of Wet, Oily Wastes/EPA's Research Facility in Edison, NJ	Theodore Trowbridge 201-887-2182	Laurel Staley 513-569-7863	Soil, Sludge, Sediment	Not Applicable	PCBs, Dioxins, Oil-Soluble Organics
E.I. DuPont de Nemours and Co. and Oberlin Filter Co., Newark, DE (003) *Demonstration Date:* April - May 1990	Membrane Microfiltration/ Palmerton Zinc Superfund Site in Palmerton, PA	Ernest Mayer 302-774-2277	John Martin 513-569-7758	Groundwater, Leachate, Wastewater, Electroplating Rinsewaters	Heavy Metals, Cyanide, Uranium	Organic Particulates, Volatile Organics
Dynaphore, Inc., Richmond, VA (006) *Demonstration Date:* April 1994	FORAGER® Sponge/National Lead Industry Site in Pedricktown, NJ	Norman Rainer 804-288-7109	Carolyn Esposito 908-906-6895	Industrial Discharge, Municipal Sewage Process Streams, Acid Mine Drainage Wastes	Metals	Not Applicable

** From Emerging Technology Program

TABLE 1 (continued)

Completed SITE Demonstration Program Projects as of October 1994

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
ECOVA Corporation, Golden, CO (006) *Demonstration Date:* May - September 1991	Bioslurry Reactor/EPA's Test and Evaluation Facility in Cincinnati, OH	William Mahaffey 303-273-7133	Ronald Lewis 513-569-7856	Soil	Not Applicable	Creosote and Petroleum Wastes
ELI Eco Logic International Inc., Rockwood, Ontario, Canada (006) *Demonstration Date:* October - November 1992	Gas-Phase Chemical Reduction Process/Middleground Landfill in Bay City, MI	Jim Nash 519-856-9591	Gordon Evans 513-569-7684	Soil, Sludge, Liquids	Not Applicable	PCBs, PAHs, Chlorinated Dioxins and Dibenzofurans, Chlorinated Solvents and Chlorophenols
ELI Eco Logic International Inc., Rockwood, Ontario, Canada (006) *Demonstration Date:* October - November 1992	Thermal Desorption Unit/ Middleground Landfill in Bay City, MI	Jim Nash 519-856-9591	Gordon Evans 513-569-7684	Soil, Sludge, Liquids	Not Applicable	PCBs, PAHs, Chlorinated Dioxins and Dibenzofurans, Chlorinated Solvents and Chlorophenols
EPOC Water, Inc., Fresno, CA (004) *Demonstration Date:* May - June 1992	Precipitation, Microfiltration, and Sludge Dewatering/Iron Mountain Superfund Site in Redding, CA	Rodney Squires 209-291-8144	Jack Hubbard 513-569-7507	Sludge, Wastewater, Leachable Soil	Heavy Metals	Pesticides, Oil, Grease
Filter Flow Technology, Inc., League City, TX (006) *Demonstration Date:* September 1993	Heavy Metals and Radionuclide Polishing Filter/DOE's Rocky Flats Plant in Denver, CO	Tod Johnson 713-332-3438	Annette Gatchett 513-569-7697	Groundwater, Industrial Wastewater	Heavy Metals, Radionuclides	Not Applicable
Funderburk & Associates (formerly HAZCON, Inc.), (001) *Demonstration Date:* October 1987	Dechlorination and Immobilization/Former Oil Processing Plant in Douglassville, PA	Not Available	Paul dePercin 513-569-7797	Soil, Sludge, Sediment	Heavy Metals	Nonspecific Organics
General Atomics, San Diego, CA (001) *Demonstration Date:* March 1989	Circulating Bed Combustor/Developer's Facility in San Diego, CA using waste from McColl Superfund Site in Fullerton, CA	Jeffrey Broido 619-455-4495	Douglas Grosse 513-569-7844	Soil, Sludge, Slurry, Liquids	Metals, Cyanide	Halogenated and Nonhalogenated Organic Compounds, PCBs

TABLE 1 (continued)

Completed SITE Demonstration Program Projects as of October 1994

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Geo-Con, Inc. Monroeville, PA (001) (2 Demonstrations) *Demonstration Date:* April - May 1988	In Situ Solidification and Stabilization Process/General Electric Service Shop Site in Hialeah, FL	Chris Ryan or Linda Ward 412-856-7700	Mary Stinson 908-321-6683	Soil, Sediment	Nonspecific Inorganics	PCBs, PCP, Other Nonspecific Organics
Geosafe Corporation, Richland, WA (002) *Demonstration Date:* March - April 1994	In Situ Vitrification/Parsons Chemical Site in Grand Ledge, MI	James Hansen 509-375-0710	Teri Richardson 513-569-7949	Soil, Sludge, Sediments	Nonspecific Inorganics	Nonspecific Organics
GIS/Solutions, Inc., Concord, CA (007) *Demonstration Dates:* August 1993 (CA) and December 1993 (D.C.)	GIS-Key™ Environmental Data Management System/ San Francisco, CA and Washington, D.C.	Charles Tupitza 510-602-9206	Richard Eilers 513-569-7809	Not Applicable	Not Applicable	Not Applicable
GRACE Dearborn Inc., Mississauga, Ontario, Canada (008) *Demonstration Date:* September 1994	DARAMEND™ Bioremediation Technology/Domtar Wood Preserving Site in Trenton, Ontario, Canada	Alan Seech or Igor Marvan 905-279-2222	Teri Richardson 513-569-7949	Soil, Sediment	Not Applicable	PAHs, PCPs, Total Petroleum Hydrocarbons
Gruppo Italimpresse (developed by Shirco Infrared Systems, Inc.), Rome, Italy (001) (2 Demonstrations) *Demonstration Dates:* August 1987 (FL) and November 1987 (MI)	Infrared Thermal Destruction/Peak Oil Superfund Site in Brandon, FL and Rose Township Superfund Site in Oakland County, MI	Rome 011-39-06-8802001 Padova 011-39-049-773490	Laurel Staley 513-569-7863	Soil, Sediment	Not Applicable	Nonspecific Organics
High Voltage Environmental Applications, Inc. (formerly Electron Beam Research Facility, Florida International University, and University of Miami),** Miami, FL (008)/(E03) *Demonstration Date:* September 1994	High-Energy Electron Irradiation/DOE's Savannah River Site in Aiken, SC	William Cooper 305-593-5330	Franklin Alvarez 513-569-7631	Water Streams, Sludge	Not Applicable	Most Organics

** From Emerging Technology Program

TABLE 1 (continued)

Completed SITE Demonstration Program Projects as of October 1994

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Horsehead Resource Development Co., Inc., Monaca, PA (004) *Demonstration Date:* March 1991	Flame Reactor/Developer's Facility in Monaca, PA using waste from National Smelting and Refining Company Superfund Site in Atlanta, GA	Regis Zagrocki 412-773-2289	Donald Oberacker 513-569-7510 Marta K. Richards 513-569-7692	Soil, Sludge, Industrial Solid Residues	Metals	Not Applicable
Hrubetz Environmental Services, Inc., Dallas, TX (007) *Demonstration Date:* January - February 1993	HRUBOUT® Process/Kelly Air Force Base in San Antonio, TX	Michael Hrubetz or Barbara Hrubetz 214-363-7833	Gordon Evans 513-569-7684	Soil	Not Applicable	Halogenated or Nonhalogenated Volatiles or Semivolatiles
Hughes Environmental Systems, Inc., (005) *Demonstration Date:* August 1991 - September 1993	Steam Enhanced Recovery Process/Fuel Spill Site in Huntington Beach, CA	Not Available	Paul dePercin 513-569-7797	Soil, Groundwater	Not Applicable	VOCs and SVOCs
IIT Research Institute/Brown and Root Environmental, Chicago, IL/Oak Ridge, TN (007) *Demonstration Date:* August 1993	Radio Frequency Heating/Kelly Air Force Base in San Antonio, TX	Harsh Dev 312-567-4257 Paul Carpenter 904-283-6187 Clifton Blanchard 615-483-9900	Laurel Staley 513-569-7863	Soil	Not Applicable	Petroleum Hydrocarbons, VOCs, SVOCs
KAI Technologies, Inc./Brown and Root Environmental, Woburn, MA/Oak Ridge, TN (008) *Demonstration Date:* January - March 1994	Radio Frequency Heating/Kelly Air Force Base in San Antonio, TX	Raymond Kasevich 617-932-3328 Paul Carpenter 904-283-6187 Clifton Blanchard 615-483-9900	Laurel Staley 513-569-7863	Soil	Not Applicable	Petroleum Hydrocarbons, VOCs, SVOCs
Magnum Water Technology, El Segundo, CA (007) *Demonstration Date:* March 1993	CAV-OX® Process/Edwards Air Force Base, CA	Dale Cox 310-322-4143 Jack Simser 310-640-7000	Richard Eilers 513-569-7809	Groundwater, Wastewater	Not Applicable	Halogenated Solvents, Phenol, Pentachlorophenol, PCBs, BTEX
Maxymillian Technologies, Inc. (formerly Clean Berkshires Inc.), Pittsfield, MA (008) *Demonstration Date:* November - December 1993	Mobile Thermal Desorption System/Niagara Mohawk Power Corporation's Harbor Point Site in Utica, NY	James Maxymillian 413-499-3050 Neal Maxymillian 617-695-9770 800-695-7771	Ronald Lewis 513-569-7856	Soil	Cyanide	VOCs, SVOCs, PAHs, and Coal Tars

TABLE 1 (continued)

Completed SITE Demonstration Program Projects as of October 1994

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
North American Technologies Group, Inc., Sacramento, CA (008) *Demonstration Date:* June 1994	Oleophilic Amine-Coated Ceramic Chip/Petroleum Products Corporation Site in Fort Lauderdale, FL	Cathryn Wimberly 916-366-6165	Laurel Staley 513-569-7863	Groundwater, Marine Wastes	Not Applicable	Gasoline, Crude Oil, Diesel Fuel, BTEX, PAHs, PCBs,PCP, Trichloroethene
NOVATERRA, Inc. (formerly Toxic Treatments USA, Inc.), Los Angeles, CA (003) *Demonstration Date:* September 1989	In Situ Steam and Air Stripping/Annex Terminal in San Pedro, CA	Philip LaMori 310-843-3190	Paul dePercin 513-569-7797	Soil	Nonspecific Inorganics, Heavy Metals	VOCs, SVOCs, Hydrocarbons
Resources Conservation Company, Ellicott City, MD (001) *Demonstration Date:* July 1992	B.E.S.T. Solvent Extraction Technology/Grand Calumet River Site in Gary, IN	Lanny Weimer 410-596-6066	Mark Meckes 513-569-7348	Soil, Sludge, Sediment	Not Applicable	Oil, PCBs, PAHs, Pesiticides, Herbicides
Retech, Inc., Ukiah, CA (002) *Demonstration Date:* July 1991	Plasma Arc Vitrification/DOE's Component Development and Integration Facility in Butte, MT	Ronald Womack or Leroy Leland 707-462-6522	Laurel Staley 513-569-7863	Soil, Sludge	Metals	Nonspecific Organics
Risk Reduction Engineering Laboratory, Cincinnati, OH (005) *Demonstration Date:* August - September 1993	Base-Catalyzed Decomposition Process/Koppers Company Superfund Site in Morrisville, NC	Carl Brunner 513-569-7655 Yei-Shong Shieh or G. Steven Detwiler 610-832-0700	Terrence Lyons 513-569-7589	Soil, Sediment, Sludge	Not Applicable	PCBs, PCPs, Halogenated Compounds
Risk Reduction Engineering Laboratory, Cincinnati, OH (007) *Demonstration Date:* November 1992	Volume Reduction Unit/ Escambia Treating Company Site in Pensacola, FL	Richard Griffiths 908-321-6629	Teri Richardson 513-569-7949	Soil	Metals	Creosote, PCPs, PAHs, VOCs, SVOCs, Pesticides
Risk Reduction Engineering Laboratory and IT Corporation, Cincinnati, OH (004) *Demonstration Dates:* September 1988 (MI), December 1989 (KY), and August 1990 (GA)	Debris Washing System/ Superfund Sites in Detroit, MI; Hopkinsville, KY; and Walker County, GA	Michael Taylor or Majid Dosani 513-782-4700	Donald Sanning 513-569-7875	Debris	Nonspecific Inorganics	Nonspecific Organics, PCBs, Pesticides

TABLE 1 (continued)

Completed SITE Demonstration Program Projects as of October 1994

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Risk Reduction Engineering Laboratory and USDA Forest Products Laboratory, Cincinnati, OH/Madison, WI (006) *Demonstration Date:* June - November 1992	Fungal Treatment Technology/ Brookhaven Wood Preserving Site in Brookhaven, MS	John Glaser 513-569-7568 Richard Lamar 608-231-9469	Teri Richardson 513-569-7949	Soil	Not Applicable	PCPs, PAHs, Chlorinated Organics
Risk Reduction Engineering Laboratory, University of Cincinnati, and FRX, Inc., Cincinnati, OH (005) *Demonstration Dates:* July 1991 - September 1992 (IL) and August 1991 - September 1992 (OH)	Hydraulic Fracturing/Xerox Corporation Site in Oak Brook, IL and an underground storage spill site in Dayton, OH	William Slack 513-556-2526	Michael Roulier 513-569-7796	Soil, Groundwater	Nonspecific Inorganics	Nonspecific Organics
Rochem Separation Systems, Inc., Torrance, CA (006) *Demonstration Date:* August 1994	Rochem Disc Tube™ Module System/Central Landfill Superfund Site in Johnston, RI	David LaMonica 310-370-3160	Douglas Grosse 513-569-7844	Liquids	Nonspecific Inorganics	Organic Solvents
RUST Remedial Services, Inc. (formerly offered by Chemical Waste Management, Inc.), Palos Heights, IL (004) *Demonstration Date:* May 1992	X*TRAX™ Thermal Desorption/ Re-Solve, Inc., Superfund Site in North Dartmouth, MA	Chetan Trivedi 708-361-7520 708-361-8400	Paul dePercin 513-569-7797	Soil, Sediment, Sludge	Heavy Metals	VOCs, SVOCs, PCBs, Dioxins
SBP Technologies, Inc., Baton Rouge, LA (005) *Demonstration Date:* October 1991	Membrane Filtration and Bioremediation/American Creosote Works in Pensacola, FL	Clayton Page 504-753-5255	John Martin 513-569-7758	Groundwater, Surface Water, Storm Water, Landfill Leachates, Industrial Process Wastewater	Not Applicable	Organic Compounds, PAHs, PCBs, TCE, PCP

TABLE 1 (continued)

Completed SITE Demonstration Program Projects as of October 1994

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
J.R. Simplot,** Pocatello, ID (006) (2 Demonstrations) *Demonstration Dates:* July 1993 (WA) and September 1993 - February 1994 (MO)	The SABRE™ Process/Bowers Field in Ellensburg, WA and Weldon Spring Ordinance Works Site in Weldon Spring, MO	Russel Kaake 208-234-5367	Wendy Davis-Hoover 513-569-7206	Soil	Not Applicable	Nitroaromatics
SoilTech ATP Systems, Inc., Porter, IN (005) (2 Demonstrations) *Demonstration Date:* May 1991 (NY); June 1992 (IL)	Anaerobic Thermal Processor/ Wide Beach Superfund Site in Brant, NY and Waukegan Harbor Superfund Site in Waukegan, IL	Alistair Montgomery 303-790-1747 Joseph Hutton 219-929-4343	Paul dePercin 513-569-7797	Soil, Sludge, Refinery Wastes	Not Applicable	PCBs, Chlorinated Pesticides, VOCs, SVOCs
Soliditech, Inc. (002) *Demonstration Date:* December 1988	Solidification and Stabilization/ Imperial Oil Company/ Champion Chemical Company Superfund Site in Morganville, NJ	Not Available	Jack Hubbard 513-569-7507	Soil, Sludge	Metals, Nonspecific Inorganics	Nonspecific Organics, Oil, Grease
Sonotech, Inc., Atlanta, GA (007) *Demonstration Date:* May - July 1994	Frequency-Tunable Pulse Combustion System/EPA's Incineration Research Facility in Jefferson, AR	Zin Plavnik 404-525-8530	Marta K. Richards 513-569-7692	Soil, Medical Waste	Nonspecific Inorganics	Nonspecific Organics
STC Omega, Inc. (formerly Silicate Technology Corporation), Scottsdale, AZ (003) *Demonstration Date:* November 1990	Chemical Fixation/Solidification Treatment Technologies/Selma Pressure Treating Superfund Site in Selma, CA	Stephen Pelger or Scott Larsen 602-948-7100	Edward Bates 513-569-7774	Soil, Sludge, Wastewater	Metals, Cyanide, Fluorides, Arsenates, Chromates, Selenium	High Molecular Weight Organics, PAHs
Terra-Kleen Response Group, Inc., Oklahoma City, OK (006) *Demonstration Date:* May - June 1994	Solvent Extraction Treatment System/Naval Air Station North Island in San Diego, CA	Alan Cash 405-728-0001	Mark Meckes 513-569-7348	Soil, Sludge, Sediment, Debris	Not Applicable	PCBs, PCP, PAH, Creosote, Chlorinated Pesticides, PCDD, PCDF

** From Emerging Technology Program

TABLE 1 (continued)

Completed SITE Demonstration Program Projects as of October 1994

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Terra Vac, Inc., San Juan, PR (001) *Demonstration Date:* December 1987 - April 1988	In Situ Vacuum Extraction/ Groveland Wells Superfund Site in Groveland, MA	James Malot 809-723-9171	Mary Stinson 908-321-6683	Soil	Not Applicable	VOCs
Texaco Inc., White Plains, NY (006) *Demonstration Date:* January 1994	Entrained-Bed Gasification/ Developer's Montebello Research Laboratory using a mixture of soil from the Purity Oil Sales Superfund Site in Fresno, CA	Richard Zang 914-253-4047	Marta K. Richards 513-569-7692	Soil, Sludge, Sediment	Nonspecific Inorganics	Nonspecific Organics
Toronto Harbour Commission, Toronto, Ontario, Canada (006) *Demonstration Date:* April - May 1992	Soil Recycling/Toronto Port Industrial District in Toronto, Ontario, Canada	Carol Moore 416-863-2071	Teri Richardson 513-569-7949	Soil	Nonspecific Inorganics	Nonspecific Organics
Ultrox, A Division of Zimpro Environmental, Inc., Santa Ana, CA (003) *Demonstration Date:* March 1989	Ultraviolet Radiation and Oxidation/Lorentz Barrel and Drum Company in San Jose, CA	David Fletcher 714-545-5557	Norma Lewis 513-569-7665	Groundwater, Leachate, Wastewater	Not Applicable	Halogenated Solvents, VOCs, Pesticides, PCBs, BTEX
United States Environmental Protection Agency, San Francisco, CA (007) *Demonstration Date:* June - July 1990	Excavation Techniques and Foam Suppression Methods/ McColl Superfund Site in Fullerton, CA	John Blevins 415-774-2400	Jack Hubbard 513-569-7507	Soil	Not Applicable	VOCs
Vulcan Peroxidation Systems, Inc. (formerly Peroxidation Systems, Inc.), Tucson, AZ (006) *Demonstration Date:* September 1992	**perox-pure**™ Chemical Oxidation Technology/Lawrence Livermore National Laboratory in Altamont Hills, CA	Chris Giggy 602-790-8383	Norma Lewis 513-569-7665	Groundwater, Wastewater	Not Applicable	Fuel Hydrocarbons, Chlorinated Solvents, PCBs, VOCs, SVOCs
WASTECH Inc., Oak Ridge, TN (004) *Demonstration Date:* August 1991	Solidification and Stabilization/ Robins Air Force Base in Warner Robins, GA	Benjamin Peacock 615-483-6515	Terrence Lyons 513-569-7589	Soil, Sludge, Liquid Waste	Nonspecific Radioactive Inorganics	Nonspecific Organics

TABLE 1 (continued)

Completed SITE Demonstration Program Projects as of October 1994

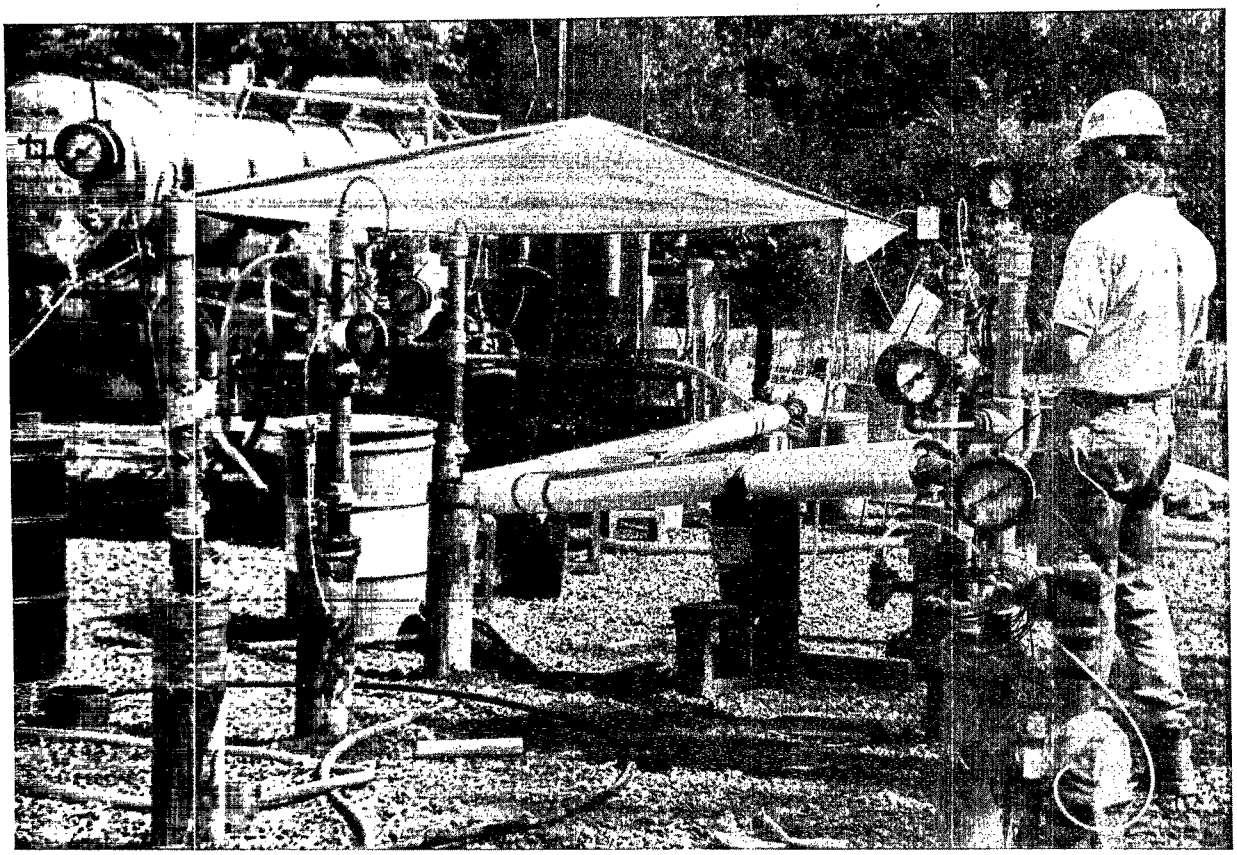
Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Roy F. Weston, Inc., West Chester, PA (006) *Demonstration Date:* November - December 1991	Low Temperature Thermal Treatment (LT³®) System/ Anderson Development Company Superfund Site in Adrian, MI	Mike Cosmos 610-701-7423	Paul dePercin 513-569-7797	Soil, Sludge	Not Applicable	VOCs, SVOCs, Petroleum Hydrocarbons, PAHs
Roy F. Weston, Inc./IEG Technologies, Woodland Hills, CA/Charlotte, NC (008) *Demonstration Date:* May 1993 - May 1994	UVB - Vacuum Vaporizing Well/March Air Force Base, CA	Jeff Bannon 818-596-6900 Eric Klingel 704-357-6090	Michelle Simon 513-569-7469	Groundwater	Heavy Metals	VOCs, SVOCs
Wheelabrator Clean Air Systems, Inc. (formerly Chemical Waste Management, Inc.), Schaumburg, IL (005) *Demonstration Date:* September 1992	PO*WW*ER™ Technology/ Chemical Waste Management's Facility in Lake Charles, LA	Annamarie Connolly 708-706-6900	Randy Parker 513-569-7271	Wastewater, Leachate, Groundwater	Metals, Volatile Inorganic Compounds, Salts, Radionuclides	VOCs and Nonvolatile Organic Compounds

ACCUTECH REMEDIAL SYSTEMS, INC.
(Pneumatic Fracturing Extraction℠ and Catalytic Oxidation)

TECHNOLOGY DESCRIPTION:

Accutech Remedial Systems, Inc. (Accutech), and the Hazardous Substance Management Research Center located at the New Jersey Institute of Technology in Newark, New Jersey have jointly developed an integrated treatment system that combines Pneumatic Fracturing Extraction℠ (PFE℠) with hot gas injection (HGI). The system provides a cost-effective, accelerated approach for remediating less permeable formations contaminated with halogenated and nonhalogenated volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) (see photograph below). The system forces compressed gas into a formation at pressures that exceed the natural in situ stresses present, creating a fracture network. These fractures allow subsurface air to circulate faster and more efficiently throughout the formation, which can greatly improve contaminant mass removal rates. PFE℠ also increases the effective area that can be influenced by each extraction well, while intersecting new pockets of contamination that were previously trapped in the formation. Thus, VOCs can be removed faster and from a larger section of the formation.

PFE℠ can combine with a catalytic oxidation unit equipped with special catalysts to destroy halogenated organics. The heat from the catalytic oxidation unit can be recycled to the formation, significantly raising the vapor pressure of the contaminants. Thus, VOCs volatilize faster, which makes cleanup more efficient.



Pneumatic Fracturing Extraction℠ and Catalytic Oxidation

The SITE Program assesses but does not approve or endorse technologies.

PFE^{SM} can couple with HGI, an in situ thermal process, to further enhance VOC removal rates. HGI returns the energy generated during catalytic oxidation of the VOCs to the ground. The PFE^{SM}-HGI integrated treatment system is cost-effective for treating soil and rock formations where conventional in situ technologies have limited effectiveness due to less permeable geologic formations. Activated carbon is used when contaminant concentrations decrease to levels where catalytic oxidation is no longer cost-effective.

WASTE APPLICABILITY:

The system can remove halogenated and non-halogenated VOCs and SVOCs from both the vadose and saturated zones. The integrated treatment system is cost-effective for treating soils and rock when less permeable geologic formations limit the effectiveness of conventional in situ technologies.

STATUS:

This technology was accepted into the SITE Demonstration Program in December 1990. Phase 1 of the demonstration was conducted in summer 1992 at a New Jersey Department of Environmental Protection and Energy Environmental Cleanup Responsibility Act site in Hillsborough, New Jersey. During Phase 1, trichloroethene and other VOCs were removed from a siltstone formation. Results of this demonstration were published in the following documents available from EPA:

- Technology Evaluation Report (EPA/540/R-93/509)
- Technology Demonstration Summary (EPA/540/SR-93/509)
- Demonstration Bulletin (EPA/540/MR-93/509)
- Applications Analysis Report (EPA/540/AR-93/509)

DEMONSTRATION RESULTS:

The demonstration results indicate that PFE^{SM} increased the effective vacuum radius of influence nearly threefold. PFE^{SM} also increased the rate of mass removal up to 25 times over the rates measured using conventional extraction technology.

The PFE^{SM}-HGI process is being demonstrated in a two-phase approach. The incremental benefit of each technology was evaluated in the first phase. In the second phase, the technologies will be integrated with a groundwater recovery process and the catalytic technology to evaluate long-term cost benefits. A Phase 2 demonstration is planned for 1994.

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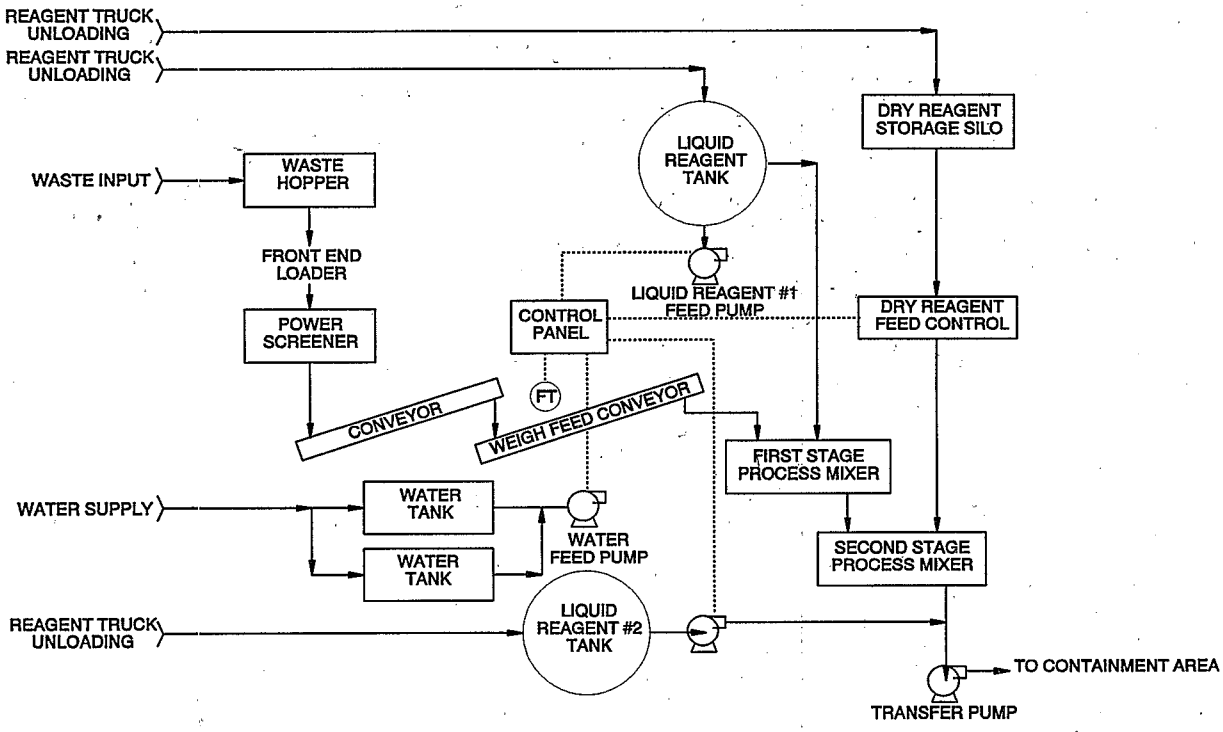
The SITE Program assesses but does not approve or endorse technologies.

ADVANCED REMEDIATION MIXING, INC.
(formerly Chemfix Technologies/CeTech Resources)
(Solidification and Stabilization)

TECHNOLOGY DESCRIPTION:

In this solidification and stabilization process, pozzolanic materials react with polyvalent metal ions and other waste components to produce a chemically and physically stable solid material. Optional accelerators and precipitators may include soluble silicates, carbonates, phosphates, and borates. The end product may be similar to a clay-like soil, depending upon the characteristics of the raw waste and the properties desired in the end product.

Typically, the waste is first blended in a reaction vessel with pozzolanic materials that contain calcium hydroxide. This blend is then dispersed throughout an aqueous phase. The reagents react with one another and with toxic metal ions, forming both anionic and cationic metal complexes. Pozzolanic accelerators and metal precipitating agents can be added before or after the dry binder is initially mixed with the waste. When a water soluble silicate reacts with the waste and the pozzolanic binder system, colloidal silicate gel strengths are increased within the binder-waste matrix helping polyvalent metal cations. A large percentage of the heavy metals become part of the calcium silicate and aluminate colloidal structures formed by the pozzolans and calcium hydroxide. Some of the metals, such as lead, adsorb to the surface of the pozzolanic structures. The entire pozzolanic matrix, when physically cured, decreases toxic metal mobility by reducing the incursion of leaching liquids into and out of the stabilized matrices. With modifications, the system (shown below) may be applied to wastes containing between 10 to 100 percent solids.



Process Flow Diagram

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

This process is suitable for contaminated soils, sludges, ashes, and other solid wastes. The process is particularly applicable to electroplating sludges, electric arc furnace dust, heavy metal contaminated soils, oil field drilling muds and cuttings, municipal sewage sludges, and residuals from other treatment processes. This process effectively treats heavy metals, such as antimony, arsenic, lead, cadmium, hexavalent chromium, mercury, copper, and zinc. In addition, when combined with specialized binders and additives, this process can stabilize low-level nuclear wastes.

STATUS:

The solidification and stabilization process was demonstrated in March 1989 at the Portable Equipment Salvage Company site in Clackamas, Oregon. The Technology Evaluation Report was published in September 1990 (EPA/540/5-89/011a). The Applications Analysis Report was completed in May 1991 (EPA/540/A5-89/011).

In addition, several full-scale remediation projects have been completed since 1977, including a high solids CHEMSET® reagent protocol designed to treat 30,000 cubic yards of hexavalent chromium-contaminated, high solids waste. The average chromium level after treatment was less than 0.15 milligram per liter and met toxicity characteristic leaching procedure (TCLP) criteria. The final product permeability was less than 1×10^{-4} centimeters per second (cm/sec).

DEMONSTRATION RESULTS:

The demonstration yielded the following results:

- The technology effectively reduced copper and lead concentrations in the wastes. The concentrations in the TCLP extracts from the treated wastes were 94 to 99 percent less than those from the untreated wastes. Total lead concentrations in the untreated waste approached 14 percent.
- The volume of excavated waste material increased between 20 to 50 percent after treatment.
- During the durability tests, the treated wastes showed little or no weight loss after 12 cycles of wetting and drying or freezing and thawing.
- The unconfined compressive strength of the wastes varied between 27 and 307 pounds per square inch after 28 days. Hydraulic conductivity of the treated material ranged between 1×10^{-6} cm/sec and 6.4×10^{-7} cm/sec.
- Air monitoring data suggest there was no significant volatilization of polychlorinated biphenyls during the treatment process.
- Treatment costs were approximately $73 per ton, including mobilization, labor, reagents, and demobilization, but not disposal.

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The SITE Program assesses but does not approve or endorse technologies.

AMERICAN COMBUSTION, INC.
(PYRETRON® Thermal Destruction)

TECHNOLOGY DESCRIPTION:

The PYRETRON® thermal destruction technology controls the heat input during incineration using PYRETRON® oxygen-air-fuel burners to control excess oxygen available to oxidize hazardous waste (see figure below). The PYRETRON® combustor relies on a new technique for mixing auxiliary oxygen, air, and fuel to 1) provide the flame envelope with enhanced stability, luminosity, and flame core temperature, and 2) increase the British thermal units (Btu) per volume of heat released.

The technology is computer-controlled to automatically adjust the temperatures of the primary and secondary combustion chambers and the amount of excess oxygen. The system adjusts the amount of excess oxygen in response to sudden changes in contaminant volatilization rates in the waste.

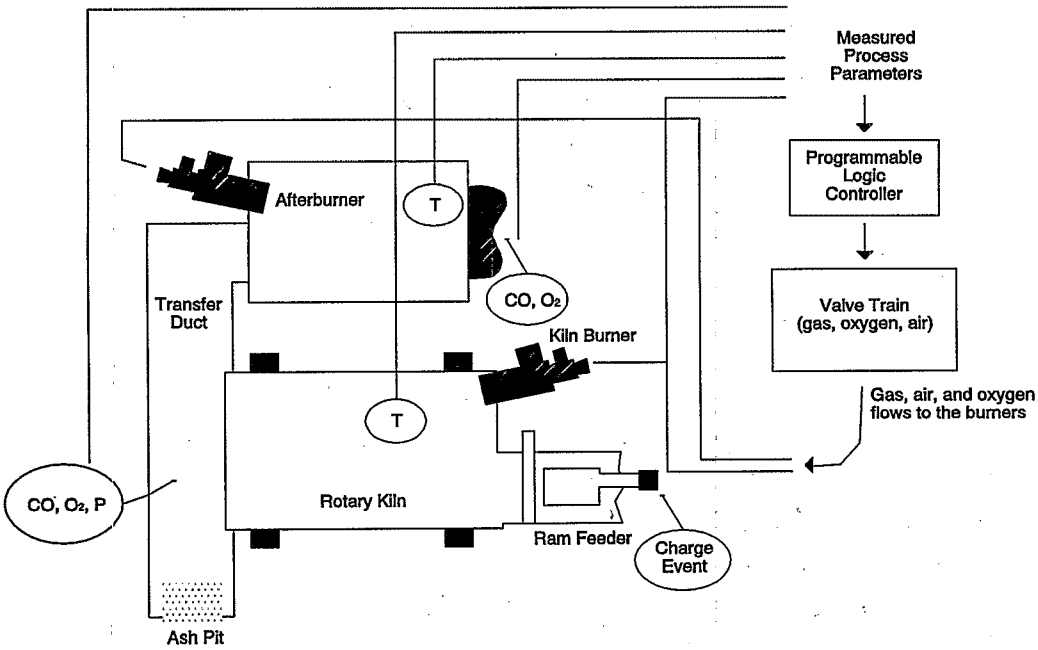
The technology fits any conventional incineration unit and can burn liquids, solids, and sludges. Solids and sludges can also be coincinerated when the burner is used with a rotary kiln or similar equipment.

WASTE APPLICABILITY:

The PYRETRON® technology treats high- and low-Btu solid wastes contaminated with rapidly-volatilized hazardous organics. In general, the technology treats any waste that can be incinerated. It is not suitable for processing aqueous wastes, Resource Conservation and Recovery Act heavy metal wastes, or inorganic wastes.

STATUS:

The PYRETRON® technology was demonstrated at EPA's Incineration Research Facility in Jefferson, Arkansas, using a mixture of 40



PYRETRON® Thermal Destruction System

The SITE Program assesses but does not approve or endorse technologies.

percent contaminated soil from the Stringfellow Acid Pit Superfund site in California and 60 percent decanter tank tar sludge (K087) from coking operations. The demonstration began in November 1987 and was completed at the end of January 1988.

Both the Technology Evaluation Report (EPA/540/5-89/008) and Applications Analysis Report (EPA/540/A5-89/008) have been published.

DEMONSTRATION RESULTS:

Six polynuclear aromatic hydrocarbons, naphthalene, acenaphthylene, fluorene, phenanthrene, anthracene, and fluoranthene, were selected as the principal organic hazardous constituents (POHC) for the test program.

The PYRETRON® technology achieved greater than 99.99 percent destruction and removal efficiencies of all POHCs measured in all test runs performed. Other results are listed below:

- The PYRETRON® technology with oxygen enhancement doubled the waste throughput possible with conventional incineration.
- All particulate emission levels from the scrubber system discharge were significantly below the hazardous waste incinerator performance standard of 180 milligrams per dry standard cubic meter at 7 percent oxygen that existed until May 1993.
- Solid residues were contaminant-free.
- There were no significant differences in transient carbon monoxide level emissions between air-only incineration and PYRETRON® oxygen-enhanced operation with doubled throughput rate.
- Cost savings increase when operating and fuel costs are high and oxygen costs are relatively low.
- The system can double the capacity of a conventional rotary kiln incinerator. This increase is more significant for wastes with low heating values.

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The SITE Program assesses but does not approve or endorse technologies.

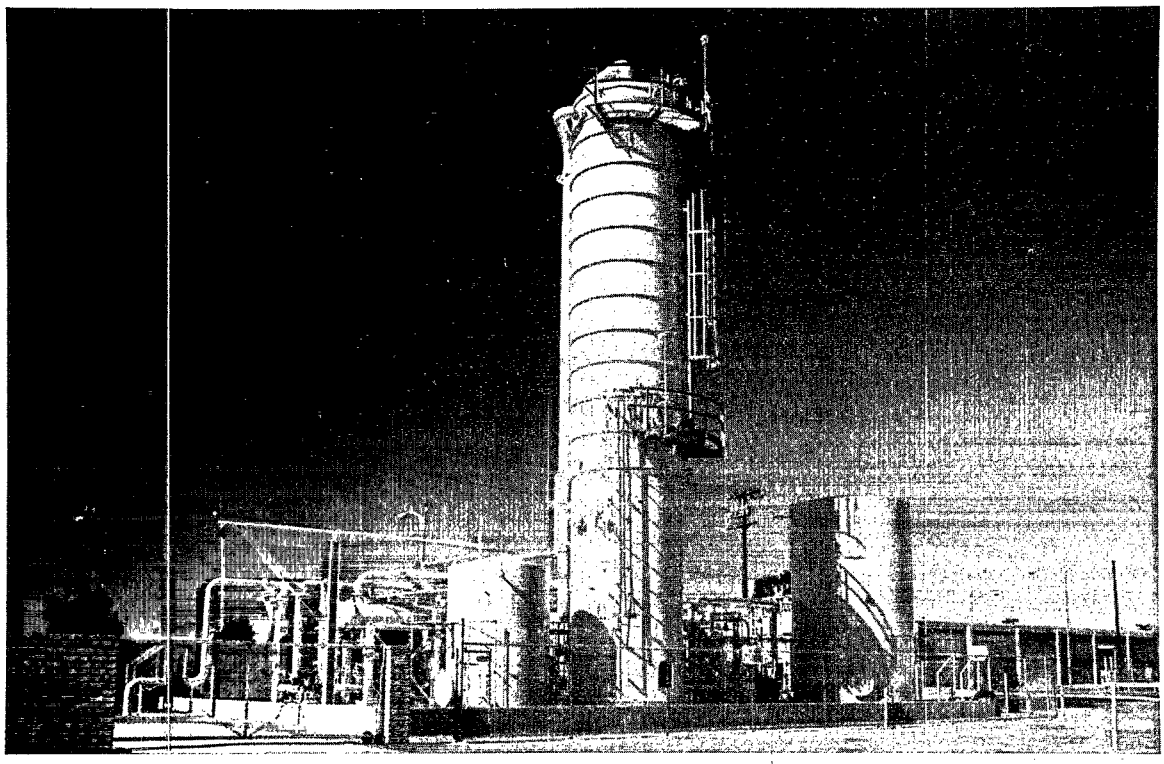
AWD TECHNOLOGIES, INC.
(Integrated Vapor Extraction and Steam Vacuum Stripping)

TECHNOLOGY DESCRIPTION:

The integrated AquaDetox/soil gas vapor extraction/reinjection (SVE) system simultaneously treats groundwater and soil contaminated with volatile organic compounds (VOC). The integrated system consists of 1) an AquaDetox moderate vacuum stripping tower that uses low-pressure steam to treat contaminated groundwater, and 2) an SVE process to treat contaminated soil. The two processes form a closed-loop system that simultaneously remediates contaminated groundwater and soil in situ with no air emissions.

AquaDetox is a high-efficiency, countercurrent stripping technology developed by Dow Chemical Company. A single-stage unit typically reduces VOCs in water up to 99.99 percent. The SVE system uses a vacuum to treat VOC-contaminated soil, inducing a flow of air through the soil and removing vapor phase VOCs with the extracted soil gas. Carbon beds remove additional VOCs from the soil gas, which is then reinjected into the ground. The AquaDetox and SVE systems share a granulated activated carbon (GAC) unit that decontaminates the combined vapors from both systems (see photograph below). By-products of the system are a free-phase recyclable product and treated water. Mineral regenerable carbon will require disposal after about 3 years.

A key element of the closed-loop system is the vent header unit. This unit collects the noncondensable gases extracted from the groundwater or air that may leak into the part of the process operating below atmospheric pressure. Also, the AquaDetox system condenses and treats the steam used to regenerate the carbon beds.



Zero Air Emissions Integrated AquaDetox/SVE System

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

This technology removes VOCs, including chlorinated hydrocarbons, in groundwater and soil. Sites with contaminated groundwater and soils containing trichloroethene (TCE), tetrachloroethene (PCE), and other VOCs are suitable for this on-site treatment process.

STATUS:

The AWD AquaDetox/SVE system has been treating groundwater and soil gas at the Lockheed Aeronautical Systems Company in Burbank, California, for over 3 years. The groundwater is contaminated with as much as 2,200 parts per billion (ppb) of TCE and 11,000 ppb PCE; the soil gas has a total VOC concentration of 6,000 parts per million. Contaminated groundwater is treated at a rate of up to 1,200 gallons per minute (gpm), while soil gas is removed and treated at a rate of 300 cubic feet per minute. The system occupies about 4,000 square feet. It has been operational 95 percent of the time, with 5 percent downtime due to scheduled or nonscheduled repairs.

In September 1990, a SITE demonstration was conducted as part of ongoing remediation at the San Fernando Valley Groundwater Basin Superfund site in Burbank, California. The Applications Analysis Report (EPA/540/A5-91/002) was published in October 1991.

DEMONSTRATION RESULTS:

During testing at the San Fernando Valley Superfund site, the AquaDetox/SVE system achieved the following results:

- The AWD technology successfully treated groundwater and soil gas contaminated with VOCs.
- Efficiencies were in the 99.92 to 99.99 percent range for removal of VOCs from contaminated groundwater. VOC removal efficiencies for soil gas ranged from 98.0 to 99.9 percent when the GAC beds were regenerated according to the AWD-specified frequency (8-hour shifts). VOC removal efficiencies dropped to as low as 93.4 percent when the GAC beds were regenerated less frequently.
- The AWD technology produced effluent groundwater that complied with regulatory discharge requirements for TCE and PCE (5 micrograms per liter for each compound).
- The GAC beds effectively removed VOCs from contaminated soil gas even after 24 hours of continuous operation without steam regeneration.
- The system's steam consumption dropped with decreasing tower pressures. During the demonstration, the system was more efficient at lower operating tower pressures.
- The AWD system is estimated to cost approximately $3.2, $4.3, and $5.8 million for the 500-, 1,000-, and 3,000-gpm systems, respectively. The total annual operation and maintenance costs are approximately $410,000, $630,000 and $1,500,000 for the 500-, 1,000-, and 3,000-gpm systems, respectively.

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The SITE Program assesses but does not approve or endorse technologies.

BABCOCK & WILCOX CO.
(Cyclone Furnace)

TECHNOLOGY DESCRIPTION:

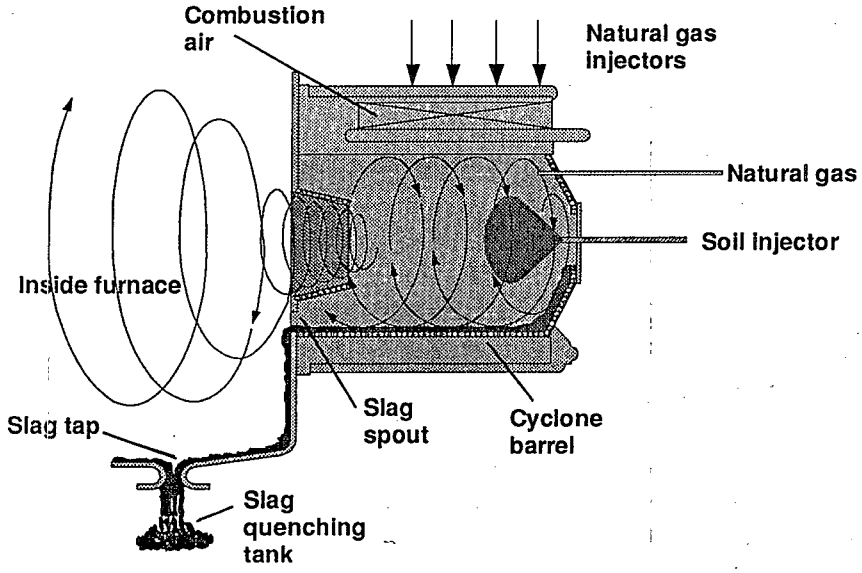
The Babcock & Wilcox Co. (Babcock & Wilcox) cyclone furnace is designed to combust high inorganic content (high-ash) coal. Through cofiring, the cyclone furnace can also accommodate highly contaminated wastes containing heavy metals and organics in soil or sludge. High heat-release rates of 45,000 British thermal units (Btu) per cubic foot of coal and high turbulence in cyclones ensures the high temperatures required for melting the high-ash fuels. The inert ash exits the cyclone furnace as a vitrified slag.

The furnace is water-cooled and simulates the geometry of Babcock & Wilcox's single-cyclone, front-wall-fired cyclone boilers. The pilot-scale cyclone furnace, shown in the figure below, is a scaled-down version of a commercial coal-fired cyclone with a restricted exit (throat). The furnace geometry is a horizontal cylinder (barrel).

Natural gas and preheated combustion air are heated to 820 degrees Fahrenheit (°F) and enter tangentially into the cyclone burner. For dry soil processing, the soil matrix and natural gas enter tangentially along the cyclone furnace barrel. For wet soil processing, an atomizer uses compressed air to spray the soil paste directly into the furnace. The soil or sludge and inorganics are captured and melted, and organics are destroyed in the gas phase or in the molten slag layer. This slag layer is formed and retained on the furnace barrel wall by centrifugal action.

The soil melts, exits the cyclone furnace from the tap at the cyclone throat, and drops into a water-filled slag tank where it solidifies. A small quantity of soil also exits as fly ash with the flue gas from the furnace and is collected in a baghouse. In principle, this fly ash can be recycled to the furnace to increase metal capture and to minimize the volume of the potentially hazardous waste stream.

The energy requirements for vitrification are 15,000 Btu per pound of soil treated. Given the much larger surface-to-volume ratio of the relatively small pilot unit and its cool surface, a full-scale unit can be expected to have proportionally lower energy requirements. The cyclone furnace can be operated with gas, oil, or coal as the supplemental fuel. The waste may also supply a significant portion of the required heat input.



Cyclone Furnace

The SITE Program assesses but does not approve or endorse technologies.

Particulates are controlled by a baghouse. To maximize the capture of metals, a heat exchanger is used to cool the stack gases to approximately 200 °F before they enter the baghouse.

WASTE APPLICABILITY:

The cyclone vitrification technology is applicable to highly contaminated hazardous wastes, sludges, and soils that contain heavy metals and organic constituents. The wastes may be solid, a soil slurry (wet soil), or liquids. To be treated in the cyclone furnace, the ash or solid matrix must melt (with or without additives) and flow at cyclone furnace temperatures (2,400 to 3,000 °F). Because the technology captures heavy metals in the slag and renders them nonleachable, it is an important treatment application for soils that contain lower-volatility radionuclides such as strontium and transuranics.

STATUS:

The cyclone vitrification technology was accepted into the SITE Demonstration Program in August 1991. A SITE demonstration occurred in November 1991 at the developer's facility. The process was demonstrated using an EPA-supplied, wet, synthetic soil matrix (SSM) spiked with heavy metals (lead, cadmium, and chromium), organics (anthracene and dimethylphthalate), and simulated radionuclides (bismuth, strontium, and zirconium). The SSM was processed at a feed rate of 170 pounds per hour. Almost 3 tons of SSM were processed during the demonstration. The Applications Analysis Report (EPA/520/AR-92/017) and Technology Evaluation Report [Vol. 1 (EPA/504/R-92/017A), Vol. 2 (EPA/540/R-92/017B) are available from EPA.

DEMONSTRATION RESULTS:

The vitrified slag toxicity characteristic leaching procedure (TCLP) leachabilities were 0.29 milligram per liter (mg/L) for lead, 0.12 mg/L for cadmium, and 0.30 mg/L for chromium (all pass the EPA TCLP limits). Almost 95 percent of the noncombustible SSM was incorporated into the slag. Greater than 75 percent of the chromium, 88 percent of the strontium, and 97 percent of the zirconium were captured in the slag. Dry weight volume was reduced 28 percent. Destruction and removal efficiencies for anthracene and dimethylphthalate were greater than 99.997 percent and 99.998 percent, respectively. Stack particulates were 0.001 grains per dry standard cubic feet (gr/dscf) at 7 percent oxygen, which was below the Resource Conservation Recovery Act limit of 0.08 gr/dscf effective until May 1993. Carbon monoxide and total hydrocarbons in the flue gas were 6.0 parts per million (ppm) and 8.3 ppm, respectively. The simulated radionuclides were immobilized in the vitrified slag as measured using the American Nuclear Society 16.1 Method.

An independent cost analysis was performed as part of the SITE demonstration. The cost to remediate 20,000 tons of contaminated soil using a 3.3-ton-per-hour unit is estimated at $465 per ton if the unit is on-line 80 percent of the time or $529 per ton if the unit is on-line 60 percent of the time.

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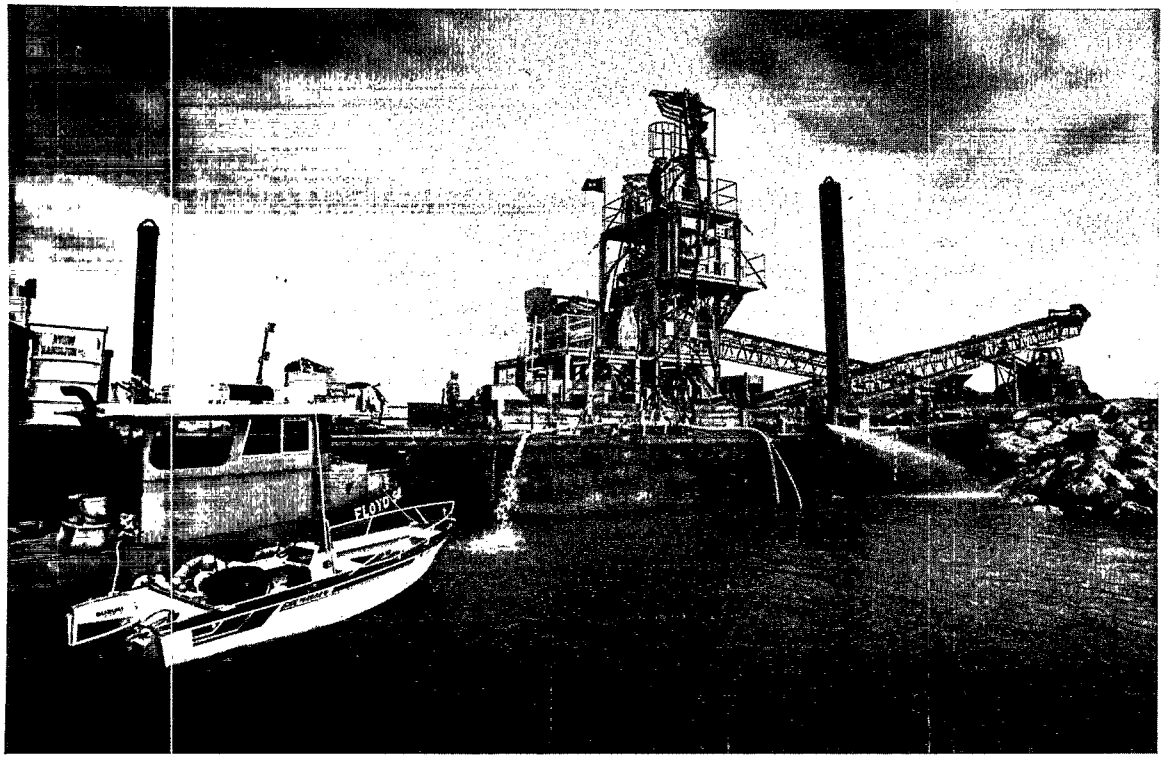
The SITE Program assesses but does not approve or endorse technologies.

BERGMANN USA
(Soil and Sediment Washing)

TECHNOLOGY DESCRIPTION:

The Bergmann USA soil and sediment washing technology separates contaminated particles by density and grain size (see photograph below). The technology operates on the hypothesis that most contamination is concentrated in the fine particle fraction (-63 micron [μm] fines), and that contamination of larger particles is generally not extensive.

After contaminated soil is screened to remove coarse rock and debris, water and chemical additives such as surfactants, acids, bases, and chelants, are added to the soil to produce a slurry feed. The slurry feed flows to an attrition scrubbing machine. A rotary trammel screen, dense media separators, cyclone separators, and other equipment create mechanical and fluid shear stress, removing contaminated silts and clays from granular soil particles. Different separation processes then create the following four output streams: 1) coarse clean fraction; 2) enriched fine fraction; 3) separated contaminated humic; and 4) process wash water. The coarse clean fraction material, which measures 45 μm (greater than 325 mesh), can be used as backfill or recycled for concrete, masonry, or asphalt sand application. The enriched fine fraction, measuring less that 45 μm is prepared for subsequent treatment, immobilization, destruction or regulated disposal. Separated contaminated humic materials (leaves, twigs, roots, grasses, wood chips) are dewatered and require subsequent treatment or disposal. The process wash water is treated by flocculation/sedimentation, oil/water separation, and/or dissolved air flotation to remove solubilized heavy metal



Bergmann USA Soil and Sediment Washing

The SITE Program assesses but does not approve or endorse technologies.

fractions. The treated process wash water is then returned to the plant for re-use operations. Upflow classification and separation, also known as elutriation, separates light contaminated specific gravity materials such as contaminated leaves, twigs, roots, or wood chips.

WASTE APPLICABILITY:

This washing technology is suitable for treating soils and sediment contaminated with polychlorinated biphenyls (PCB). The soil and sediment technology has been applied to soils and sediments contaminated with organics and heavy metals, including cadmium, chromium, lead, creosote, copper, cyanides, fuel residues, mercury, heavy petroleum, lead, nickel, PCBs, radionuclides, and zinc.

STATUS:

This technology was accepted into the SITE Demonstration Program in winter 1991. It was demonstrated in Toronto, Ontario, Canada, in April 1992 (see Toronto Harbour Commissioners profile in this document), and Saginaw, Michigan, in May 1992. Twenty-eight commercial systems, ranging up to 350 tons per hour, have been applied at contaminated waste sites. The Applications Analysis Report and Technology Evaluation Report for the demonstration in Saginaw, Michigan, will be available in late 1994.

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The SITE Program assesses but does not approve or endorse technologies.

BERKELEY ENVIRONMENTAL RESTORATION CENTER
(formerly Udell Technologies, Inc.)
(In Situ Steam Enhanced Extraction Process)

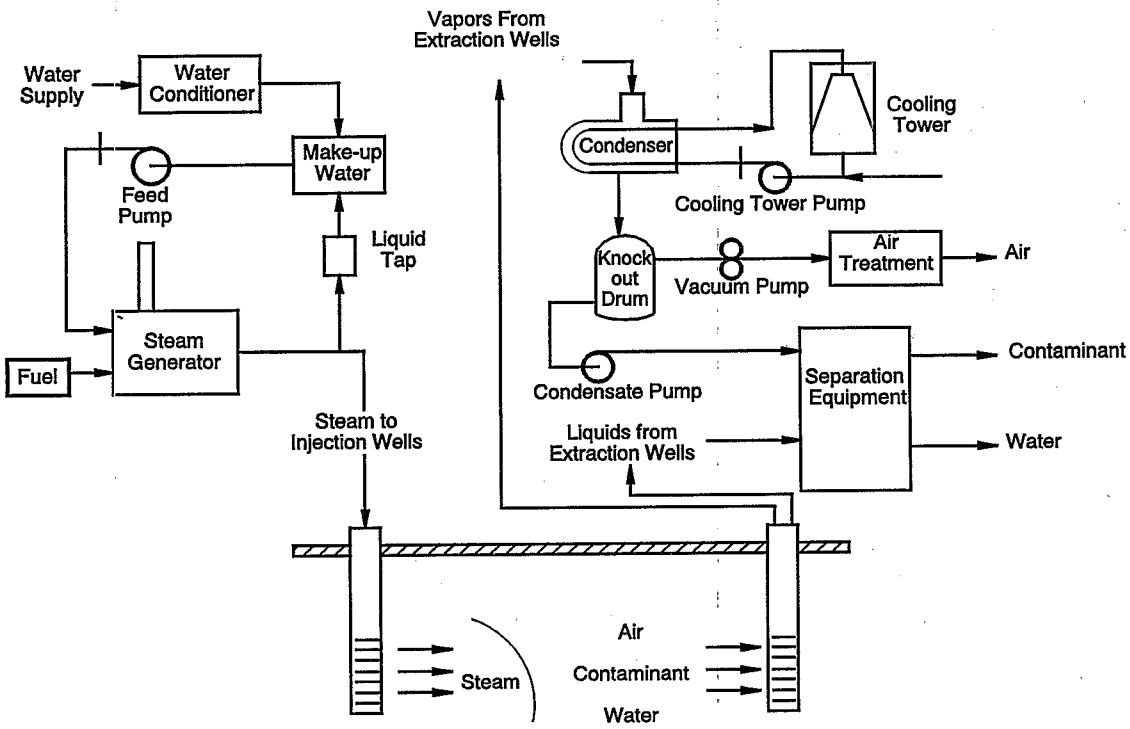
TECHNOLOGY DESCRIPTION:

The in situ steam enhanced extraction (ISEE) process removes volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) from contaminated soils above and below the water table (see figure below). Injection wells force steam through the soil to thermally enhance the vapor and liquid extraction processes.

The extraction wells have two purposes: 1) to pump and treat groundwater; and 2) to transport steam and vaporized contaminants under vacuum to the surface. Recovered contaminants are condensed and processed with the contaminated groundwater, or trapped by gas-phase activated carbon filters. The ISEE process uses readily available components such as injection, extraction and monitoring wells; manifold piping; vapor and liquid separators; vacuum pumps; and gas emission control equipment.

WASTE APPLICABILITY:

The ISEE process extracts VOCs and SVOCs from contaminated soils and groundwater. The primary compounds suitable for treatment include hydrocarbons such as gasoline, diesel, and jet fuel; solvents such as trichloroethene, trichloroethane, and dichlorobenzene; or a mixture of these compounds. The process may be applied to contaminants above or below the water table. After treatment is complete, subsurface conditions are excellent for biodegradation of residual contaminants, if necessary. The process cannot be applied to contaminated soil very near the surface unless a cap exists. Compounds denser



In Situ Steam Enhanced Extraction Process

The SITE Program assesses but does not approve or endorse technologies.

than water may be treated only in low concentrations, unless a barrier exists or can be created to prevent downward percolation of a separate phase.

STATUS:

In August 1988, a successful pilot-scale demonstration of the ISEE process was completed at a site contaminated with a mixture of solvents. Contaminants amounting to 764 pounds were removed from the 10-foot-diameter, 12-foot-deep test region. After 5 days of steam injection, soil contaminant concentrations dropped by a factor of 10.

A full-scale demonstration was completed at Lawrence Livermore National Laboratory in Altamont Hills, California, in December 1993. Gasoline was dispersed both above and below groundwater due to a 25-foot rise in the water table since the spill occurred. The lateral distribution of second liquid phase gasoline was within a region of 150 feet in diameter. In 26 weeks of operation, free product gasoline was recovered from regions both above and below the water table. Recovery rates were about 50 times greater than those that were achieved by vacuum extraction and groundwater pumping alone. The majority of the recovered gasoline came from the condenser as a separate phase liquid or in the effluent air steam. Over 7600 gallons of gasoline was recovered; the rates were highest during cyclic steam injection, after subsurface soils reached steam temperatures. Without further pumping, 1,2-dichloroethene, ethylbenzene, toluene, and xylene concentrations in sampled groundwater were decreased to below maximum contaminant levels (MCL) after 6 months. Benzene concentrations remain above the MCL, but are decreasing with time. Post-process soil sampling indicates that a thriving hydrocarbon-degrading microbial population exists in soils experiencing prolonged steam contact.

A pilot-scale test of ISEE is now underway at Naval Air Station (NAS) Lemoore in Alameda, California. During 3 months of operation, over 100,000 gallons of JP-5 has been recovered from medium permeability, partially-saturated sand to a depth of 20 feet. Preliminary soil sampling shows reductions of JP-5 soil concentrations from several thousand parts per million (ppm) above the water table to values less than 25 ppm.

Additional site demonstrations are planned at NAS Lemoore in the coming year. Potential sites include a shallow aviation gasoline spill and a small trichloroethene spill.

For more information about this technology, see the Hughes Environmental Systems, Inc. (Completed Projects) and the Praxis Environmental Technologies, Inc., (Ongoing Projects) profiles in the Demonstration Program section.

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The SITE Program assesses but does not approve or endorse technologies.

BILLINGS AND ASSOCIATES, INC.
(Subsurface Volatilization and Ventilation System [SVVS®])

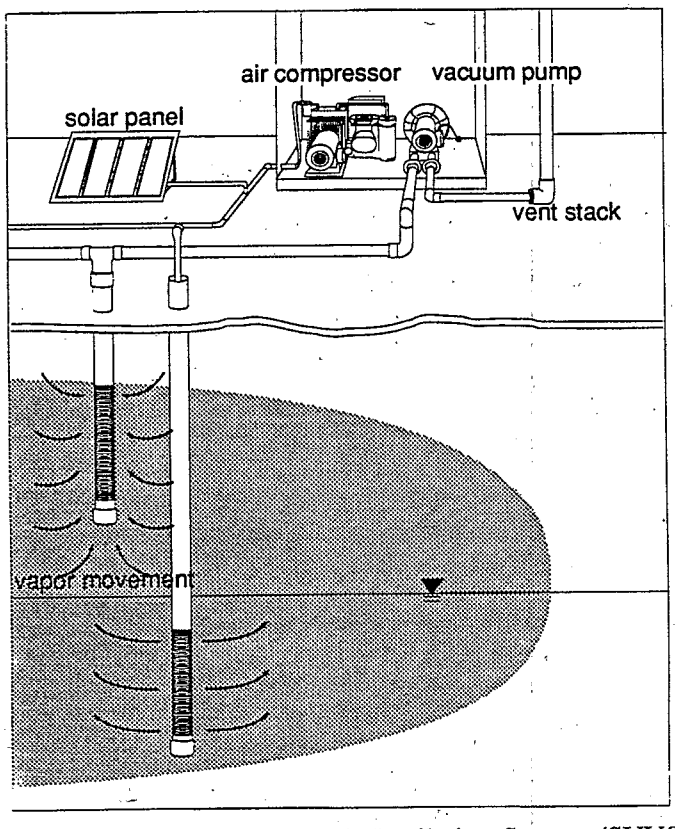
TECHNOLOGY DESCRIPTION:

The SVVS®, developed by Billings and Associates, Inc. (BAI), and operated by several other firms under a licensing agreement, uses a network of injection and extraction wells (collectively, a reactor nest) to treat subsurface organic contamination through soil vacuum extraction combined with in situ biodegradation. Each system is custom-designed to meet site-specific conditions.

A series of injection and extraction wells is installed at a site. One or more vacuum pumps create negative pressure to extract contaminant vapors, while an air compressor simultaneously creates positive pressure, sparging the subsurface treatment area. Control is maintained at a vapor control unit that houses pumps, control valves, gauges, and other process control hardware. At most underground storage tank (UST) sites, for example, extraction wells are placed above the water table and injection wells are placed below the groundwater. This placement allows the groundwater to be used as a diffusion device.

The number and spacing of the wells depends on the modeling results of applying a design parameter matrix, as well as the physical, chemical, and biological characteristics of the site. The exact depth of the injection wells and screened intervals are additional design considerations.

To enhance vaporization, solar panels are occasionally used to heat the injected air. Additional valves for limiting or increasing air flow and pressure are placed on individual reactor nest lines (radials) or, at some sites, on individual well points. Depending on groundwater depths and fluctuations, horizontal vacuum screens,



Subsurface Volatilization and Ventilation System (SVVS)

The SITE Program assesses but does not approve or endorse technologies.

"stubbed" screens, or multiple-depth completions can be applied. The system is dynamic: positive and negative air flow can be shifted to different locations at the site to place the most remediation stress on the areas requiring it. Negative pressure is maintained at a suitable level to prevent escape of vapors.

Because it provides oxygen to the subsurface, the SVVS® can enhance in situ bioremediation at a site. The technology, unlike most air sparging systems, is designed to enhance bioremediation. Thus, it can decrease remediation time significantly. These processes are normally monitored by measuring dissolved oxygen levels in the aquifer, recording carbon dioxide levels in transmission lines and at the emission point, and periodically sampling microbial populations. If air quality permits require, volatile organic compound emissions can be treated by a patent-pending biological filter that uses indigenous microbes from the site.

BAI is focusing on increasing the microbiological effectiveness of the system and completing the testing of a mobile unit. The mobile unit will allow rapid field pilot tests to support the design process. This unit will also permit actual remediation of small sites and of small, recalcitrant areas on large sites.

WASTE APPLICABILITY:

The SVVS® is applicable to sites with leaks or spills of gasoline, diesel fuels, and other hydrocarbons, including halogenated compounds. The system is very effective on benzene, toluene, ethylbenzene, and xylene (BTEX) contamination. It can also contain contaminant plumes through its unique vacuum and air injection techniques. The technology should be effective in treating soils contaminated with virtually any material that has some volatility or is biodegradable. The technology can be applied to contaminated soil, sludges, free-phase hydrocarbon product, and groundwater. By changing the injected gases to induce anaerobic conditions and by properly supporting the microbial population, the SVVS® can remove nitrates from groundwater. The aerobic SVVS® raises the redox potential of groundwater to precipitate and remove heavy metals.

STATUS:

This technology was accepted into the SITE Demonstration Program in winter 1991. A site in Buchanan, Michigan was selected for the demonstration, and initial drilling and construction began in July 1992. The SVVS® remediated BTEX, tetrachloroethene (PCE), trichloroethene (TCE), and dichloroethene (DCE) at the site. The demonstration began in March 1993 and was completed in May 1994. Preliminary results will be available in early 1995. The SVVS® has also been implemented at 75 UST sites in New Mexico, North Carolina, South Carolina, and Florida.

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The SITE Program assesses but does not approve or endorse technologies.

BIOGENESIS ENTERPRISES, INC.
(BioGenesis℠ Soil and Sediment Washing Processes)

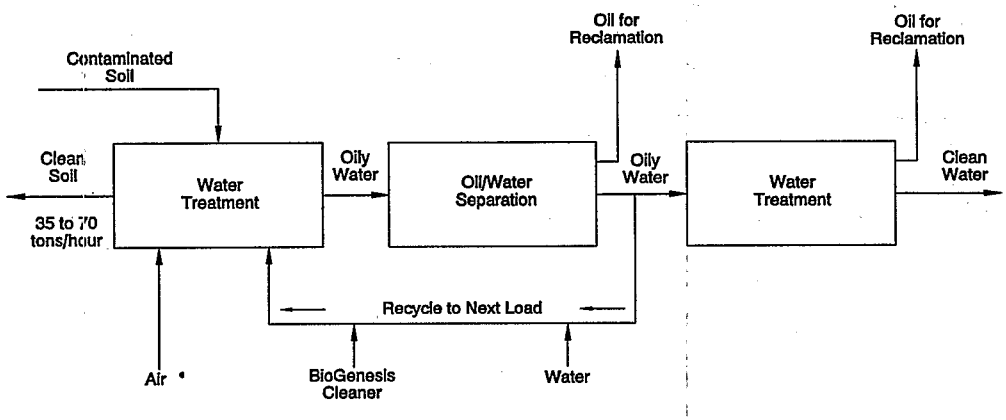
TECHNOLOGY DESCRIPTION:

The BioGenesis℠ processes use specialized, patent pending equipment, complex surfactants, and water to clean soil, sediment, and sludge contaminated with organic and inorganic constituents. Two types of mobile equipment wash different sizes of soil particles (see figure below). A truck-mounted batch unit, processing 40 yards per hour, washes soil particles 10 mesh and larger. A full-scale, mobile, continuous flow unit cleans sand, silt, clay, and sludge particles smaller than 10 mesh at a rate of 20 to 80 yards per hour. Auxiliary equipment includes tanks, dewatering and water treatment equipment, and a bioreactor. Extraction efficiencies, per wash cycle, range from 85 to 99 percent. High contaminant levels require multiple washes.

The principal components of the process include pretreatment equipment for particle sizing, a truck-mounted soil washer for larger particles, a sediment washing unit(s) for fine particles, and water treatment and reconditioning equipment. The Biogenesis℠ soil washing system for larger particles consists of a trailer-mounted gondola plumbed for air mixing, water/chemical addition, oil skimming, and liquid drainage. Water, BioGenesis™ cleaning chemicals, and soil are loaded into the gondola. Aeration nozzles feed compressed air to create a fluidized bed. The resulting slurry is agitated to release organic and inorganic contaminants from the soil particles. After mixing, a short settling period allows the soil particles to sink and the removed oil to rise to the water surface, where it is skimmed for reclamation or disposal. Following drainage of the wash water, the clean soil is evacuated by raising the unit's dump mechanism. Processed soil contains a moisture level of 10 to 20 percent depending on the soil matrix.

A prototype BioGenesis℠ sediment washing machine was tested in Environment Canada's Contaminated Sediment Treatment Technology Program. The sediment washing machine is a continuous flow unit (see figure on next page). Capacities of up to 80 to 100 cubic yards per hour are possible using full-scale, parallel processing equipment.

Sediment is pretreated to form a slurry. The slurry passes to a shaker screen separator that sizes particles into two streams. Material greater than 1 millimeter (mm) in diameter is diverted to the large particle soil washer. Material 1 mm and smaller continues to the sediment washer's feed hopper. From there the slurry is injected to the sediment cleaning chamber to loosen the bonds between the pollutant and the particle.



Soil Washing Process

The SITE Program assesses but does not approve or endorse technologies.

After the cleaning chamber, the slurry flows to the scrubber to further weaken the bonds between contaminants and particles. After the scrubber, the slurry passes through a buffer tank, where large particles separate by gravity. The slurry then flows through hydrocyclone banks to separate solids down to 3 to 5 microns in size. The free liquid routes to a centrifuge for final solid-liquid separation. All solids go to the clean soil pile; all liquid is routed to wastewater treatment to remove organic and inorganic contaminants. Decontaminated water is recycled back through the process.

The BioGenesis™ cleaning chemical is a light alkaline mixture of ionic and non-ionic surfactants and bioremediating agents that act similarly to a biosurfactant. The proprietary cleaner contains no hazardous ingredients and its characteristics were reviewed during the EPA SITE demonstration.

WASTE APPLICABILITY:

This technology extracts many inorganics, volatile and nonvolatile hydrocarbons, chlorinated hydrocarbons, pesticides, polychlorinated biphenyls, polynuclear aromatic hydrocarbons, and most organics from nearly every soil type, including clay.

STATUS:

The BioGenesis℠ soil washing technology was accepted into the SITE Demonstration Program in June 1990. The process was demonstrated at a refinery site in Minnesota. Results from the demonstration have been published in the Innovative Technology Evaluation Report (EPA/540/R-93/510) and the SITE Technology Capsule (EPA/540/SR-93/510). The reports are available from EPA. The BioGenesis℠ sediment washing technology is scheduled for PCB testing under the SITE Demonstration Program in November 1994.

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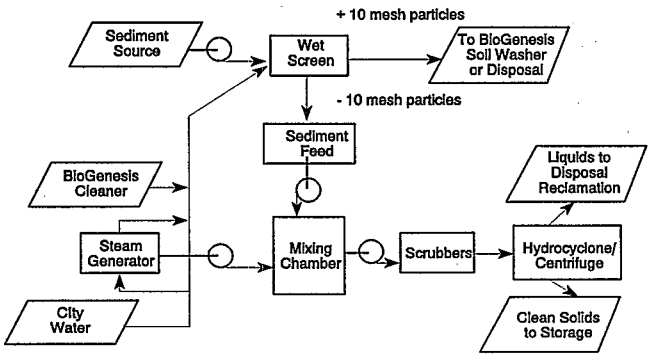


Sediment Washing Process

BIO-REM, INC.
(Augmented In Situ Subsurface Bioremediation Process)

TECHNOLOGY DESCRIPTION:

Bio-Rem, Inc.'s, Augmented In Situ Subsurface Bioremediation Process uses a proprietary blend (H-10) of microaerophilic bacteria and micronutrients for subsurface bioremediation of hydrocarbon contamination in soil and water (see figure below). The insertion methodology is adaptable to site-specific situations. The bacteria are hardy and can treat contaminants in a wide temperature range. The process does not require additional oxygen or oxygen-producing compounds, such as hydrogen peroxide. Degradation products include carbon dioxide and water.

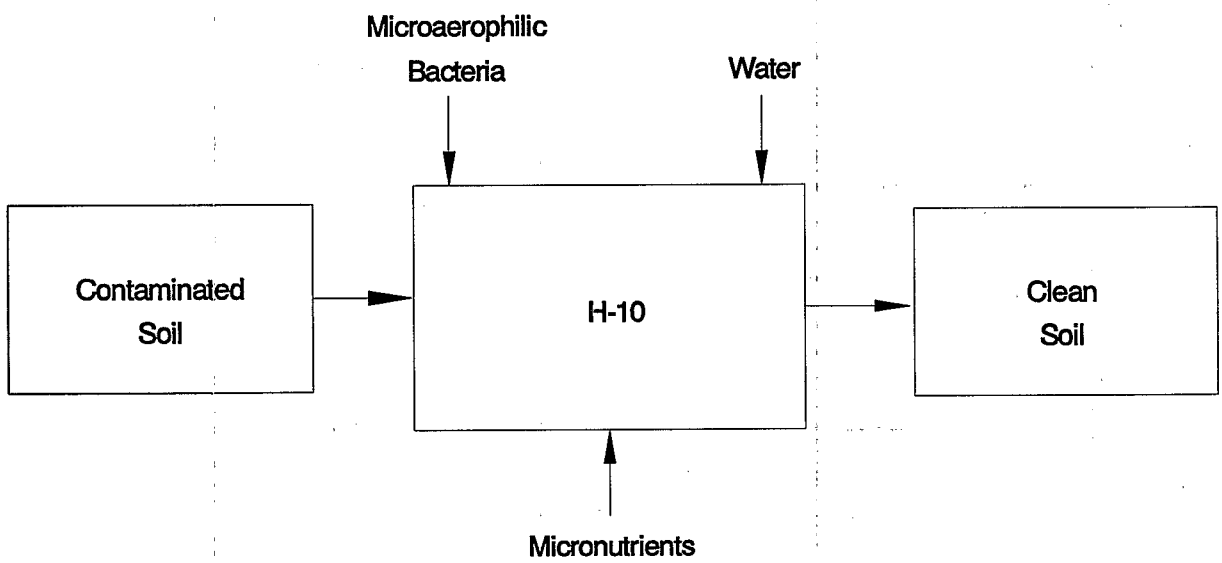
The bioremediation process consists of four steps: 1) defining and characterizing the contamination plume; 2) selecting a site-specific application methodology; 3) initiating and propagating the bacterial culture; and 4) cleanup monitoring and reporting.

WASTE APPLICABILITY:

This technology treats soil and water contaminated with hydrocarbons, halogenated hydrocarbons, and chlorinated compounds. This technology can successfully treat about 240 compounds.

STATUS:

This technology was accepted into the SITE Demonstration Program in winter 1991. The technology was demonstrated at Williams Air Force Base in Phoenix, Arizona from May 1992 through June 1993. SITE Program final reports have not been published.



Augmented In Situ Subsurface Bioremediation Process

The SITE Program assesses but does not approve or endorse technologies.

Bio-Rem, Inc., has remediated sites in Illinois, Michigan, Indiana, Texas, Kentucky, Ohio, Arizona, Connecticut, Florida, Georgia, Vermont, Oklahoma, Virginia, Nevada, California, Missouri, and Washington.

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The SITE Program assesses but does not approve or endorse technologies.

BIOTROL, INC.
(Biological Aqueous Treatment System)

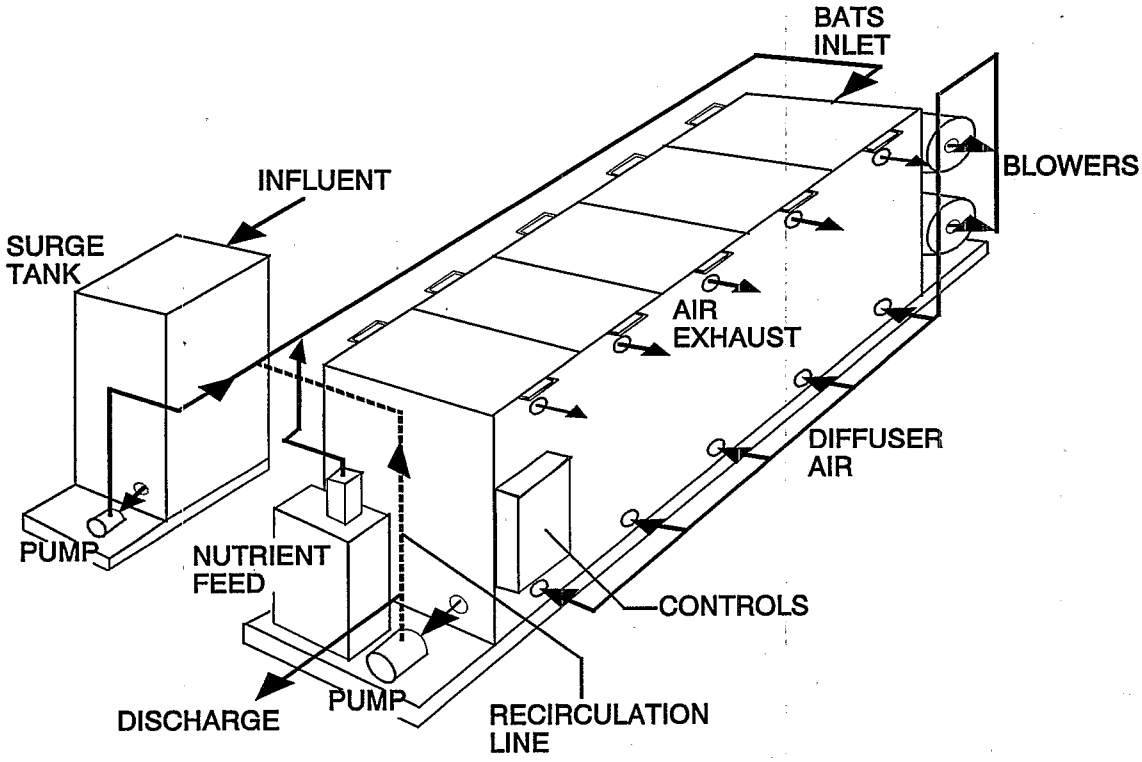
TECHNOLOGY DESCRIPTION:

The BioTrol aqueous treatment system (BATS) is a patented biological system that effectively treats contaminated groundwater and process water. The system uses naturally occurring microbes; in some instances, however, a specific microorganism may be added. This technique, known as microbial amendment, is important if a highly toxic or recalcitrant target compound is present. The amended microbial system removes both the target contaminant and the background organic carbon.

The figure below is a schematic of the BATS. Contaminated water enters a mix tank, where the pH is adjusted and inorganic nutrients are added. If necessary, the water is heated to an optimum temperature with a heater and a heat exchanger, to minimize energy costs. The water then flows to the bioreactor, where the contaminants are biodegraded.

The microorganisms that degrade the contaminants are immobilized in a multiple-cell, submerged, fixed-film bioreactor. Each cell is filled with a highly porous packing material to which the microbes adhere. For aerobic conditions, air is supplied by fine bubble membrane diffusers mounted at the bottom of each cell. The system may also run under anaerobic conditions.

As water flows through the bioreactor, the contaminants are degraded to biological end-products, predominantly carbon dioxide and water. The resulting effluent may be discharged to a publicly owned treatment works or reused



BioTrol Aqueous Treatment System (BATS)

The SITE Program assesses but does not approve or endorse technologies.

on site. In some cases, discharge with a National Pollutant Discharge Elimination System permit may be possible.

WASTE APPLICABILITY:

The BATS may be applied to a wide variety of wastewaters, including groundwater, lagoons, and process water. Contaminants amenable to treatment include pentachlorophenol (PCP), creosote components, gasoline and fuel oil components, chlorinated hydrocarbons, phenolics, and solvents. Other potential target waste streams include coal tar residues and organic pesticides. The BATS may also be effective for treating certain inorganic compounds such as nitrates; however, this application has not yet been demonstrated. The system does not treat metals.

STATUS:

During 1986 and 1987, BioTrol, Inc., performed a successful 9-month pilot field test of the BATS at a wood preserving facility. Since that time, the firm has installed more than 20 full-scale systems and has performed several pilot-scale demonstrations. These systems have successfully treated gasoline, mineral spirit solvent, phenol, and creosote-contaminated waters.

The BATS was demonstrated under the SITE Program from July 24 to September 1, 1989 at the MacGillis and Gibbs Superfund site in New Brighton, Minnesota. The system operated continuously for 6 weeks at three different flow rates. The Applications Analysis Report (EPA/540/A5-91/001) has been published. The Technology Evaluation Report is available from National Technical Information Service, order No. PB92-110 048/AS.

DEMONSTRATION RESULTS:

For the SITE demonstration, the BATS yielded the following results:

- Reduced PCP concentrations from ~45 to 1 parts per million (ppm) or less in a single pass
- Removed 96 to 99 percent of the PCP
- Produced minimal sludge and no PCP air emissions
- Mineralized chlorinated phenolics
- Eliminated groundwater biotoxicity
- Appeared to be unaffected by low concentrations of oil and grease (~50 ppm) and heavy metals in groundwater
- Required minimal operator attention

The treatment cost per 1,000 gallons was $3.45 for a 5-gallon-per-minute (gpm) unit (pilot-scale unit) and $2.43 for a 30-gpm unit.

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The SITE Program assesses but does not approve or endorse technologies.

BIOTROL, INC.
(Soil Washing System)

TECHNOLOGY DESCRIPTION:

The BioTrol Soil Washing System is a patented, water-based volume reduction process used to treat excavated soil. The system may be applied to contaminants concentrated in the fine-size soil fraction (silt, clay, and soil organic matter) or contamination associated with the coarse (sand and gravel) soil fraction.

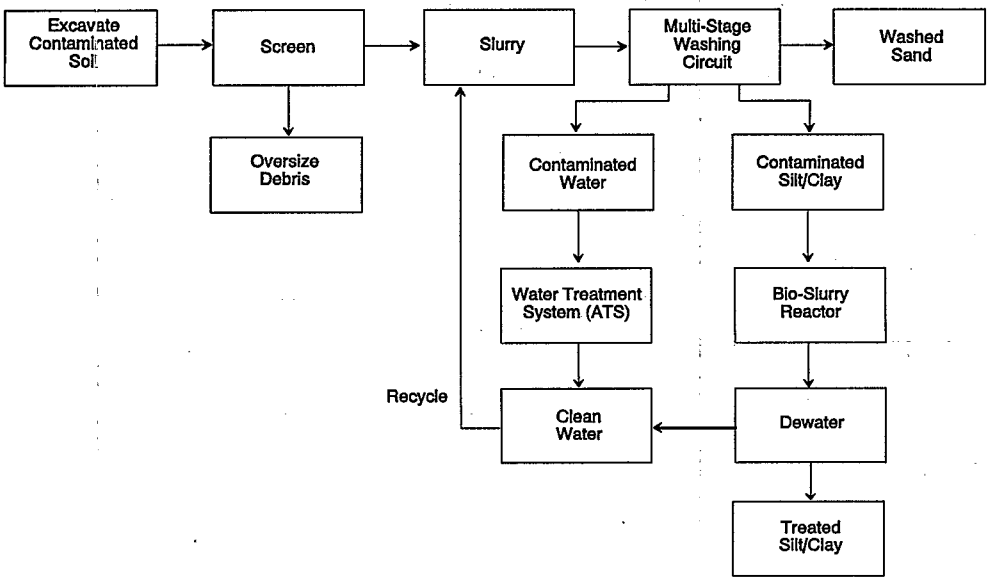
As a part of the process, debris is removed from the soil, and the soil is mixed with water and subjected to various unit operations common to the mineral processing industry. These operations can include mixing trammels, pug mills, vibrating screens, froth flotation cells, attrition scrubbing machines, hydrocyclones, screw classifiers, and various dewatering operations (see figure below).

The core of the process is a multistage, countercurrent, intensive scrubbing circuit with interstage classification. The scrubbing action disintegrates soil aggregates, freeing contaminated fine particles from the coarser material. In addition, surficial contamination is removed from the coarse fraction by the abrasive scouring action of the particles themselves. Contaminants may also be solubilized, as dictated by solubility characteristics or partition coefficients.

Contaminated residual products can be treated by other methods. Process water is normally recycled after biological or physical treatment. Contaminated fines may be disposed of off site, incinerated, stabilized, and biologically treated.

WASTE APPLICABILITY:

This system was initially developed to clean soils contaminated with wood preserving wastes, such as polynuclear aromatic hydrocarbons (PAH) and pentachlorophenol (PCP). The system may also apply to soils contaminated with petroleum hydrocarbons, pesticides, polychlorinated biphenyls (PCB), various industrial chemicals, and metals.



BioTrol Soil Washing System Process Diagram

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

The soil washing system was demonstrated under the SITE Program between September and October 1989 at the MacGillis and Gibbs Superfund site in New Brighton, Minnesota. A pilot-scale unit with a treatment capacity of 500 pounds per hour operated 24 hours per day during the demonstration. Feed for the first phase of the demonstration (2 days) consisted of soil contaminated with 130 parts per million (ppm) PCP and 247 ppm total PAHs; feed for the second phase (7 days) consisted of soil containing 680 ppm PCP and 404 ppm total PAHs.

Contaminated soil washing process water was treated biologically in a fixed-film reactor and recycled. A portion of the contaminated soil washing fines was treated biologically in a three-stage, pilot-scale EIMCO Biolift™ reactor system supplied by the EIMCO Process Equipment Company.

The Applications Analysis Report (EPA/540/A5-91/003) has been published. The Technology Evaluation Report is available from National Technical Information Service (Volume I Order No. PB92-115 310 VI, Volume II Order No. PB92-115 328-V2-PtA, and PB92-115 336-V2-PtB).

DEMONSTRATION RESULTS:

Key findings from the BioTrol demonstration are summarized below:

- Feed soil (dry weight basis) was successfully separated into 83 percent washed soil, 10 percent woody residues, and 7 percent fines. The washed soil retained about 10 percent of the feed soil contamination; 90 percent of this contamination was contained within the woody residues, fines, and process wastes.
- The soil washer removed up to 89 percent PCP and 88 percent total PAHs, based on the difference between concentration levels in the contaminated (wet) feed soil and the washed soil.
- The system degraded up to 94 percent PCP in the process water during soil washing. PAH removal could not be determined because of low influent concentrations.
- Cost of a commercial-scale soil washing system, assuming use of all three technologies, was estimated to be $168 per ton. Incineration of woody material accounts for 76 percent of the cost.

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The SITE Program assesses but does not approve or endorse technologies.

BRICE ENVIRONMENTAL SERVICES CORPORATION
(Soil Washing Plant)

TECHNOLOGY DESCRIPTION:

The Brice Environmental Services Corporation (BESCORP) soil washing plant is a portable, cost-effective, aboveground process that reduces the overall contaminated soil volume requiring treatment. BESCORP's soil washing process involves site-specific unit operations, the selection of which depends on soil and contaminant characteristics, cleanup standards, cost, and client specifications. Soil washing in its most economic applications uses a volume reduction process, in which clean oversize soil is produced by intensive scrubbing, followed by density, magnetic, and size separations. During the volume reduction process, fine contaminants that exist as discrete or attrited particles are partitioned with the soil fines, while the process water is recirculated and treated to remove suspended and dissolved contaminants.

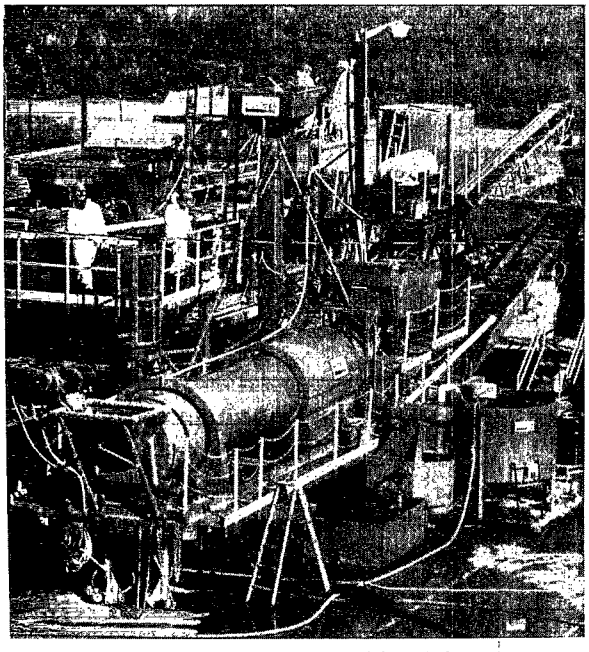
BESCORP's small volume reduction plant, used for demonstration and pilot-testing, is contained on one trailer and has a variable process rate from 4 to 20 tons per hour, depending on soil and contaminant characteristics. A full-scale plant has operated successfully since 1993, averaging 600 tons per week during summer 1994 field activities.

WASTE APPLICABILITY:

The BESCORP technology can treat soils contaminated with radioactive and heavy metals. BESCORP has also built a soil washing plant to remediate hydrocarbon-contaminated soil.

STATUS:

The BESCORP soil washing plant was accepted into the SITE Demonstration Program in winter 1991. Under the program, the BESCORP system was demonstrated in late summer 1992 on lead-contaminated soil at the Alaskan Battery Enterprises (ABE) Superfund site in Fairbanks, Alaska. Results from the demonstration are available from EPA in the Demonstration Bulletin (EPA/540/MR-93/503). The Applications Analysis Report and Technology Evaluation Report will be available in late 1994.



BESCORP Soil Washing Plant

The SITE Program assesses but does not approve or endorse technologies.

Soil washing also works as part of a process train with chemical treatment for complete soil remediation. BESCORP's volume reduction and discrete metal recovery process is linked with an acid extraction process developed by COGNIS, Inc., to remove heavy metals from contaminated soil at the Twin Cities Army Ammunition Plant (TCAAP) in New Brighton, Minnesota. Site F, located within the four square mile TCAAP site, was originally an ordnance burning and burial area. The site is part of the Army's $370 million Installation Restoration Program, and is undergoing remediation through TCAAP's Resource Conservation and Recovery Act (RCRA) permit.

At Site F, BESCORP and COGNIS, Inc., are treating lead, copper, and several other heavy metals to RCRA cleanup criteria. The technology is treating feed soils containing lead in concentrations from 3,000 to 10,000 parts per million (ppm) to under 300 ppm in a continuous 12- to 15-ton-per-hour process.

The 5-trailer, full-scale soil washing system began processing 340 tons of excavated and stockpiled material at Site F in September 1993. Cleanup goals were met, and processing continued until freezing temperatures halted cleanup until spring 1994. Operations began again in May 1994 and continued until October. The scope of work increased with the discovery of additional disposal areas at Site F, increasing the quantity of soil requiring treatment from 7,500 tons to approximately 13,000 tons. Heavy metals recovered from both the soil washing density recovery process and chemical treatment process are sent to a smelter for recycling.

DEMONSTRATION RESULTS:

The SITE demonstration of the ABE site consisted of three test runs, averaging 5 hours in duration; 48 tons of soil were processed. Excavated soil differed greatly from the treatability test soils; as a result, the BESCORP system needed extensive modifications. Preliminary results from the demonstration include the following:

- Feed soils averaged 4,500 ppm lead and the processed, separated fines fraction averaged 13,000 ppm lead.
- The system's on-line reliability was 92 percent.
- Lead removal from the combined gravel and sand fractions during the three runs were 61, 93, and 85 percent.
- Large quantities of metallic lead discovered in the excavated soil made it necessary to modify the system. The processed sand and gravel in Run 3 contained no metallic lead.
- Gravel produced by all three runs met toxicity characteristic leaching procedure (TCLP) criteria, with average lead concentrations in the TCLP leachate at 1.0, 0.8, and 0.2 milligrams per liter.
- Battery casings removal efficiencies during the three runs were 94, 100, and 90 percent.

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The SITE Program assesses but does not approve or endorse technologies.

CANONIE ENVIRONMENTAL SERVICES CORPORATION
(Low Temperature Thermal Aeration [LTTA®])

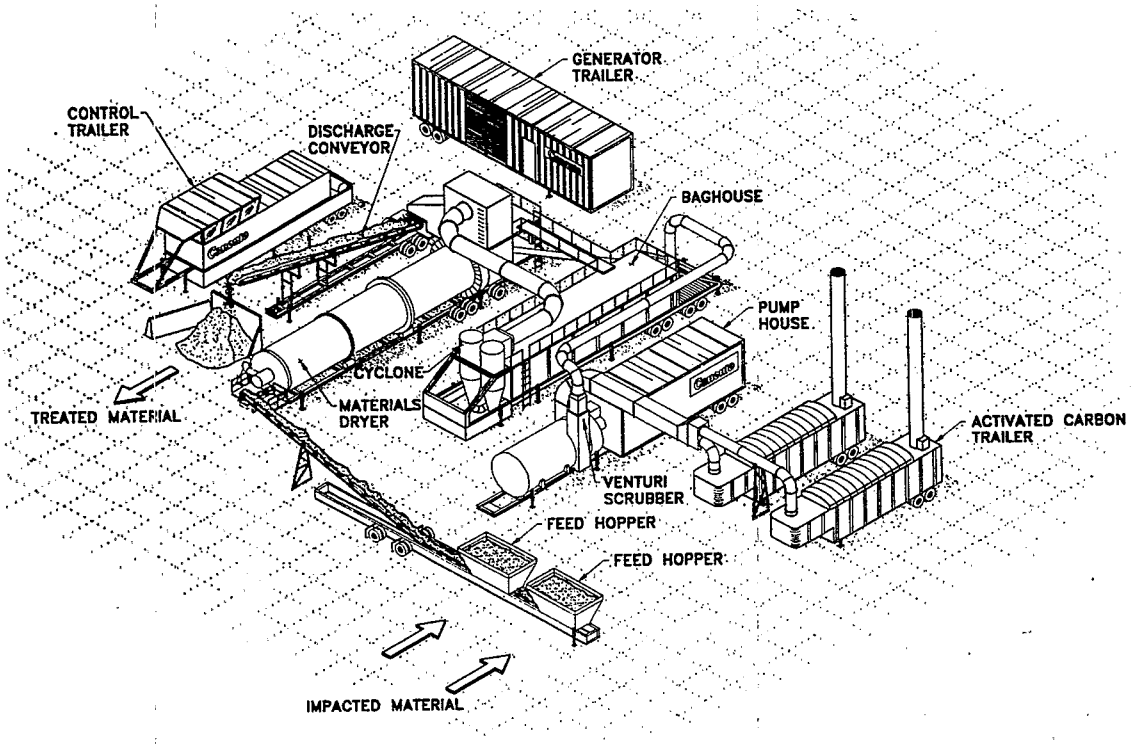
TECHNOLOGY DESCRIPTION:

The Low Temperature Thermal Aeration (LTTA®) technology is a low-temperature desorption process (see figure below). The technology removes organic contaminants from contaminated soils into a contained air stream, which is extensively treated to collect or thermally destroy the contaminants.

A direct-fired rotary dryer heats an air stream which, by direct contact, desorbs water and organic contaminants from the soil. Soil can be heated to up to 800 degrees Fahrenheit. The processed soil is quenched to reduce temperatures and mitigate dust problems. The processed soil is then discharged into a stockpile. The hot air stream that contains vaporized water and organics is treated by one of two air pollution control systems. One treatment system removes the organic contaminants from the air stream by adsorption on granular activated carbon (GAC) and includes the following units in a series: 1) cyclones and baghouse for particulate removal; 2) wet scrubber for acid gas and some organic vapor removal; and 3) GAC adsorption beds for organic removal.

The second air stream treatment system can treat soils containing high concentrations of petroleum hydrocarbons. The system includes the following units in a series: 1) cyclones for particle removal; 2) thermal oxidizer-afterburner for destruction of organics; 3) quench tower for cooling of air stream; 4) baghouse for additional particle removal; and 5) wet scrubber for acid gas removal.

The LTTA® process generates no wastewater or waste soils. Cyclone fines and baghouse dust



Low Temperature Thermal Aeration

The SITE Program assesses but does not approve or endorse technologies.

are combined with treated soil and quenched with treated scrubber water. The treated soil, once verified to meet the treatment criteria, is backfilled on site without restrictions. GAC beds used for air pollution control are regenerated or incinerated when spent.

WASTE APPLICABILITY:

LTTA® can remove volatile organic compounds (VOC), semivolatile organic compounds (SVOC), organochlorine pesticides (OCP), organophosphorus pesticides (OPP), and total petroleum hydrocarbons (TPH) from soils, sediments, and some sludges. LTTA® has been used at full scale to remove VOCs such as benzene, toluene, tetrachloroethene, trichloroethene, and dichloroethene; SVOCs such as acenaphthene, chrysene, naphthalene, and pyrene; OCPs such as dichlorodiphenyltrichloroethane (DDT); DDT metabolites, and toxaphene; OPPs such as ethyl parathion, methyl parathion, merphos, mevinphos; and TPHs.

STATUS:

The LTTA® technology was accepted into the SITE Demonstration Program in summer 1992. LTTA® was demonstrated on soils contaminated with OCPs during full-scale site remediation at a pesticide site in Arizona during September 1992.

The full-scale LTTA® system has remediated contaminated soils at six sites, including three Superfund sites. The system has treated more than 100,000 tons of soil.

DEMONSTRATION RESULTS:

Key findings from the demonstration are summarized below:

- The LTTA® process met the specified cleanup criteria for the site, a sliding scale criteria correlating the concentrations of DDT family compounds (dichlorodiphenyldichloroethylene [DDE] or tetrachlorodiphenylethane, DDE, and DDT) with concentrations of toxaphene. The maximum allowable pesticide concentrations in the treated soil were 3.52 milligrams per kilogram (mg/kg) of DDT family compounds and 1.09 mg/kg of toxaphene.
- Residual levels of all the pesticides in the treated soil were generally below or close to the laboratory detection limit, with the exception of 4,4'-DDE, which was found at residual concentrations of 0.1 to 1.5 mg/kg. Removal efficiencies for pesticides found in the feed soil at quantifiable concentrations are summarized below:

Compound	Efficiency
4,4'-DDD	>99.97%
4,4'-DDE	90.26%
4,4'-DDT	99.97%
Endrin	>99.85%
Toxaphene	>99.83%
Endosulfan 1	>99.98%

- The LTTA® process did not generate dioxins or furans as products of incomplete combustion or thermal transformation.

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The SITE Program assesses but does not approve or endorse technologies.

CF SYSTEMS CORPORATION
(Liquified Gas Solvent Extraction [LG-SX] Technology)

TECHNOLOGY DESCRIPTION:

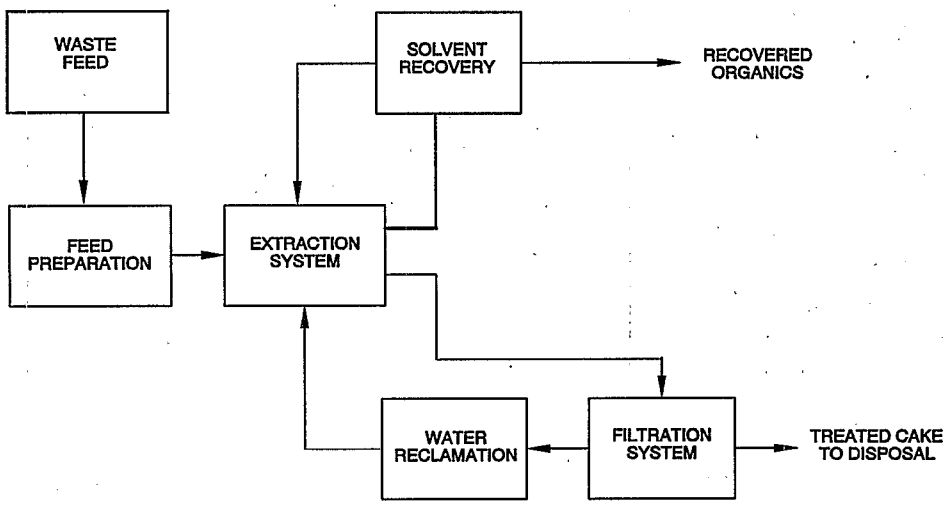
The CF Systems Corporation's LG-SX technology uses liquified gas solvents to extract organics from soils, sludges, sediments, and wastewaters. Gases, when liquified under pressure, have unique physical properties that enhance their use as solvents. The low viscosities, densities, and surface tensions of these gases result in significantly higher rates of extraction compared to conventional solvents. These enhanced physical properties also accelerate treated water's gravity settling rate following extraction. Due to their high volatility, gases are also easily recovered from the aqueous solids matrix, minimizing solvent losses.

Liquified propane solvent is typically used to treat soils, sludges, and sediments, while liquified carbon dioxide is typically used to treat wastewater. The extraction system uses a batch extractor-decanter design for solids and sludges, and a continuous trayed tower design for wastewaters and low solids wastes. Typical treatment costs for non-pumpable soils and sludges range from $80 to $300 per ton of feed, excluding excavation and disposal.

Contaminated solids, slurries, or wastewaters are fed into the extraction system along with solvent (see figure below). Typically, more than 99 percent of the organics are extracted from the feed. After the solvent and organics are separated from the treated feed, the solvent and organic mixture passes to the solvent recovery system. Once in the solvent recovery system, the solvent is vaporized and recycled as fresh solvent. The organics are drawn off and either reused or disposed of. Treated feed is discharged from the extraction system as a slurry in water.

WASTE APPLICABILITY:

The LG-SX technology can be applied to soils and sludges containing volatile and semivolatile organic compounds and other higher boiling complex organics, such as polynuclear aromatic hydrocarbons, polychlorinated biphenyls (PCB), dioxins, and pentachlorophenol. This process can also treat refinery wastes and wastewater contaminated with organics.



Solvent Extraction Remediation Process

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

Under the SITE Program, a pilot-scale mobile demonstration unit was tested in 1988 on PCB-laden sediments from the New Bedford Harbor Superfund site in Massachusetts. PCB concentrations in the harbor sediment ranged from 300 parts per million (ppm) to 2,500 ppm. The Technology Evaluation Report (EPA/540/5-90/002) and the Applications Analysis Report (EPA/540/A5-90/002) were published in August 1990.

A pilot-scale treatability study was recently completed on a PCB-contaminated soil for a Michigan Superfund site. Initial analytical data shows that treatment achieved levels of residual PCBs well below the 1 ppm cleanup level required for site closure.

CF Systems Corporation completed the first commercial on-site treatment operation at Star Enterprise, in Port Arthur, Texas. The propane-based solvent extraction unit processed listed refinery K- and F-wastes, producing Resource Conservation and Recovery Act treated solids that met EPA land-ban requirements. The unit operated continuously from March 1991 to March 1992 and was on-line more than 90 percent of the time. Following heavy metals fixation, the treated solids were disposed of in a Class I landfill.

EPA Region 6 and the Texas Water Commission have selected the LG-SX technology on a sole-source basis to cleanup the 80,000 cubic yard United Creosoting site in Conroe, Texas. This Superfund site is heavily contaminated with wood treatment wastes. Detailed design is scheduled to begin in late 1994.

DEMONSTRATION RESULTS:

This technology was demonstrated concurrently with dredging studies managed by the U.S. Army Corps of Engineers. Contaminated sediments were treated by the CF Systems Pit Clean up Unit, using a liquified propane and butane mixture as the extraction solvent. Extraction efficiencies were high, despite some operating difficulties during the tests. The demonstration at the New Bedford site yielded the following results:

- Extracted sediments were at 90 to 98 percent efficiency for sediments containing PCBs between 360 and 2,575 ppm. PCB concentrations were as low as 8 ppm in the treated sediment.
- In the laboratory, volatile and semivolatile organics in aqueous and semisolid wastes were extracted with 99.9 percent efficiency.
- Operating problems included solids retention in the system hardware and foaming in receiving tanks. The problems were corrected in the full-scale operations at Star Enterprises.
- Projected costs for PCB cleanup were estimated at $150 to $450 per ton, including material handling and pre- and posttreatment costs. These costs are highly dependent on the utilization factor and job size, which may result in lower costs for large cleanups.

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The SITE Program assesses but does not approve or endorse technologies.

DEHYDRO-TECH CORPORATION
(Carver-Greenfield Process® for Solvent Extraction of Wet, Oily Wastes)

TECHNOLOGY DESCRIPTION:

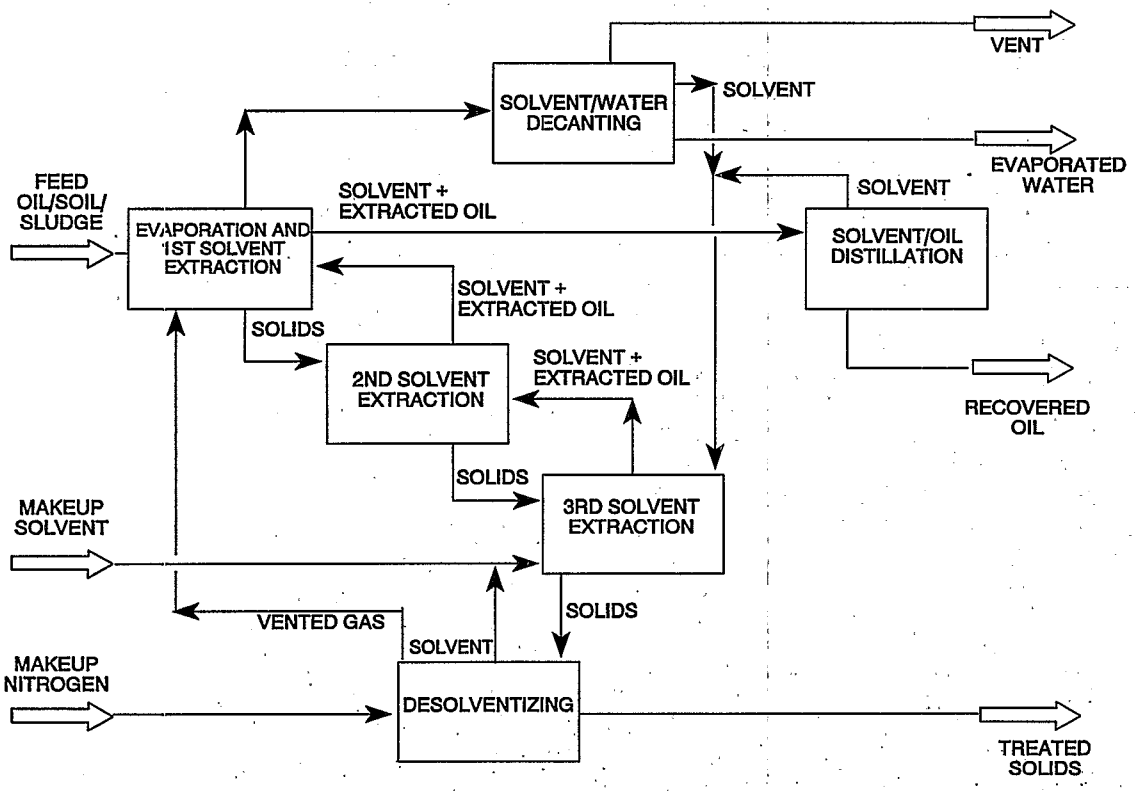
The Carver-Greenfield Process® (C-G Process™) combines solvent extraction and dehydration technologies to separate wet, oily wastes into their constituent solid phase, water phase, and hydrocarbon-soluble indigenous oil phase.

Waste is first mixed with a low cost hydrocarbon solvent, and the resultant slurry mixture is fed to an evaporator system that vaporizes water and initiates solvent extraction of the indigenous oil. Depending on the water content of the feed, single-effect or energy-saving multi-effect evaporators may be used. Next, the slurry of dried solids is treated in a multi-stage solvent extraction unit, where solids contact recycled solvent until the target amount of indigenous oil is removed.

Finally, solids are centrifuged from the solvent, followed by "desolventizing," a step where residual solvent is evaporated. The final solids product typically contains less than two percent water and less than one percent solvent. The spent solvent, which contains the extracted indigenous oil, is distilled to separate the solvent for reuse later, and the oil for recovery or disposal.

The C-G Process yields 1) a clean dry solid, 2) a water product virtually free of solids, indigenous oil, and solvent, and 3) the extracted indigenous oil which contains the hazardous hydrocarbon-soluble feed components.

The C-G Process combination of water evaporation and solvent extraction has the following advantages: 1) any emulsions initially present are broken and potential emulsion formation



Carver-Greenfield Process Schematic Diagram

The SITE Program assesses but does not approve or endorse technologies.

prevented; 2) solvent extraction is more efficient than with water present; and 3) the dry solids product is stabilized more readily if metals contamination is a concern.

WASTE APPLICABILITY:

The C-G Process can treat sludges, soils, sediments, and other water-bearing wastes containing hydrocarbon-soluble hazardous compounds, including polychlorinated biphenyls, polynuclear aromatic hydrocarbons, and dioxins. The process has been commercially applied to municipal wastewater sludge, paper mill sludge, rendering waste, pharmaceutical plant sludge, and other wastes.

STATUS:

The C-G Process was accepted into the SITE program in 1990. The pilot-scale SITE demonstration of this technology was completed in August 1991 at EPA's research facility in Edison, New Jersey. Spent petroleum drilling fluids from the PAB oil site in Abbeville, Louisiana, were used as process feed. The Applications Analysis Report (EPA/540/AR-92/002), Technology Demonstration Summary (EPA/540/SR-92/002), and Technology Evaluation Report (EPA/540/SR-92/002) were issued in 1992.

DEMONSTRATION RESULTS:

Based on spent drilling fluids, the C-G Process yielded the following SITE demonstration results:

- The process successfully separates a petroleum-oil contaminated sludge into its solid, indigenous oil, and water phases. No detectable levels of indigenous total petroleum hydrocarbons are present in the final solid product.
- The final solid product is a dry powder similar to bentonite. A food-grade solvent comprises the bulk of the residual hydrocarbons on the solid.
- Values for all metals and organics are well below the Resource Conservation and Recovery Act toxicity characteristic leaching procedure limits for characteristic hazardous wastes.
- The resulting water product requires treatment due to the presence of small amounts of light organics and solvent. Normally, it may be disposed of at a local publicly owned treatment works.
- A full scale C-G Process can treat drilling fluid wastes at technology-specific costs of $100 to $220 per ton of wet feed, exclusive of disposal costs for the residuals. Site-specific costs, which include the cost of residual disposal, are dependent on site characteristics and treatment objectives.

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The SITE Program assesses but does not approve or endorse technologies.

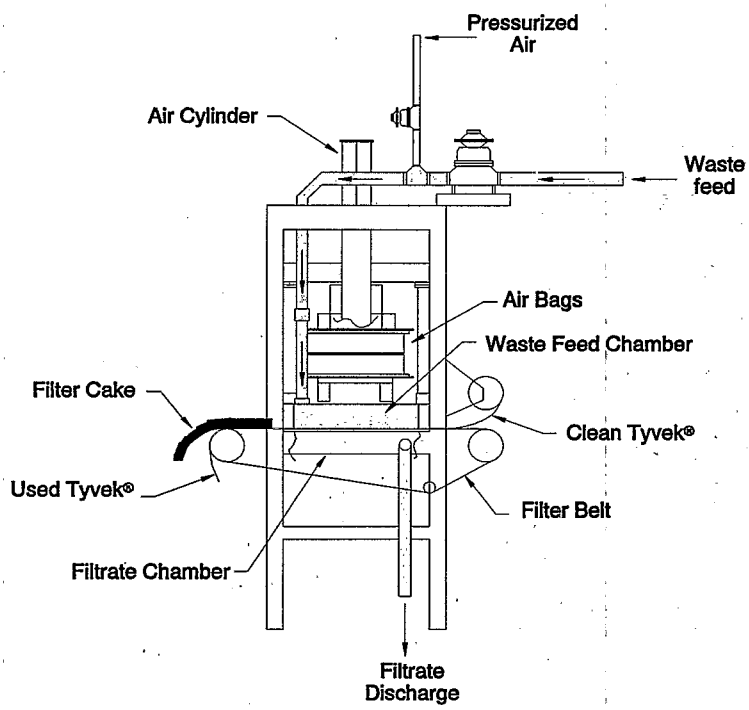
E.I. DUPONT DE NEMOURS AND COMPANY, and OBERLIN FILTER COMPANY
(Membrane Microfiltration)

TECHNOLOGY DESCRIPTION:

This membrane microfiltration system is designed to remove solid particles from liquid wastes, forming filter cakes typically ranging from 40 to 60 percent solids. The system can be manufactured as an enclosed unit, requires little or no attention during operation, is mobile, and can be trailer-mounted.

The membrane microfiltration system uses an automatic pressure filter (developed by Oberlin Filter Company), combined with a special Tyvek filter material (Tyvek T-980) made of spun-bonded olefin (invented by E.I. DuPont De Nemours and Company) (see figure below). The filter material is a thin, durable plastic fabric with tiny openings about 1 ten-millionth of a meter in diameter. These openings allow water or other liquids and solid particles smaller than the openings to flow through. Solids in the liquid stream that are too large to pass through the openings accumulate on the filter and can be easily collected for disposal.

The automatic pressure filter has two chambers: an upper chamber for feeding waste through the filter, and a lower chamber for collecting the filtered liquid (filtrate). At the start of a filter cycle, the upper chamber is lowered to form a liquid-tight seal against the filter. The waste feed is then pumped into the upper chamber and through the filter. Filtered solids accumulate on the Tyvek surface, forming a filter cake, while filtrate collects in the lower chamber. Following filtration, air is fed into the upper chamber at a pressure of about 45 pounds per square inch. Air removes any liquid remaining in the upper



DuPont/Oberlin Microfiltration System

The SITE Program assesses but does not approve or endorse technologies.

chamber and further dries the filter cake. When the filter cake is dry, the upper chamber is lifted, and the filter cake is automatically discharged. Clean filter material is then drawn from a roll into the system for the next cycle. Both the filter cake and the filtrate can be collected and treated further before disposal, if necessary.

WASTE APPLICABILITY:

This membrane microfiltration system may be applied to 1) hazardous waste suspensions, particularly liquid heavy metal- and cyanide-bearing wastes (such as electroplating rinsewaters), 2) groundwater contaminated with heavy metals, 3) constituents such as landfill leachate, and 4) process wastewaters containing uranium. The technology is best suited for treating wastes with solid concentrations of less than 5,000 parts per million; otherwise, the cake capacity and handling become limiting factors. The system can treat any type of solids, including inorganics, organics, and oily wastes, with a wide variety of particle sizes. Moreover, because the unit is enclosed, the system can treat liquid wastes that contain volatile organics.

STATUS:

The membrane microfiltration system, accepted into the SITE Program in 1988, was demonstrated at the Palmerton Zinc Superfund site in Palmerton, Pennsylvania. Groundwater from the shallow aquifer at the site was contaminated with dissolved heavy metals, including cadmium, lead, and zinc. This contaminated groundwater served as the feed waste for the demonstration. The system treated waste at a rate of about 1 to 2 gallons per minute.

The demonstration was conducted over a 4-week period in April and May 1990. An Applications Analysis Report (EPA/540/A5-90/007), a Technology Evaluation Report (EPA/540/5-90/007) and a videotape of the demonstration have been completed.

Two commercial installations of the technology began operating in 1991.

DEMONSTRATION RESULTS:

During the demonstration at the Palmerton Zinc Superfund site, the DuPont/Oberlin microfiltration system achieved the following results:

- Removal efficiencies for zinc and total suspended solids ranged from 99.75 to 99.99 percent (averaging 99.95 percent).
- Solids in the filter cake ranged from 30.5 to 47.1 percent.
- Dry filter cake in all test runs passed the Resource Conservation and Recovery Act paint filter liquids test.
- Filtrate met the applicable National Pollutant Discharge Elimination System standard for zinc.
- A composite filter cake sample passed the extraction procedure toxicity and toxicity characteristic leaching procedure tests for metals.

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The SITE Program assesses but does not approve or endorse technologies.

DYNAPHORE, INC.
(FORAGER® Sponge)

TECHNOLOGY DESCRIPTION:

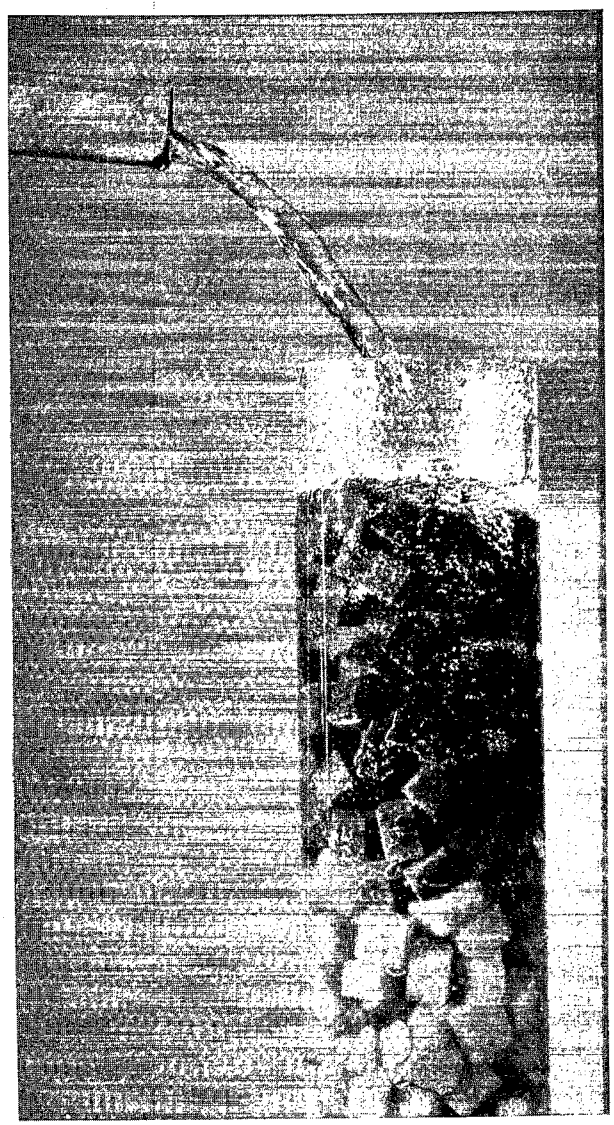
The FORAGER® Sponge is an open-celled cellulose sponge with an amine-containing polymer that has a selective affinity for aqueous heavy metals in both cationic and anionic states. The polymer tends to form complexes with ions of transition-group heavy metals, providing ligand sites that surround the metal and form a coordination complex. The polymer's order of affinity for metals is influenced by solution parameters such as pH, temperature, and total ionic content. In general, the following affinity sequence for several representative ions is expected:

$Cd^{++} > Cu^{++} > Fe^{+++} > Au^{+++} > Mn^{++} > Zn^{++} > Ni^{++} > Co^{++} > Pb^{++} > Au(CN)_2^- > SeO_4^{-2} > AsO_4^{-3} > Hg^{++} > CrO_4^{-2} > Ag^+ > Al^{+++} > Ca^{++} > Mg^{++}$

During absorption, a cation is displaced from the polymer. The displaced cation may be H^+ or a cation below the absorbed cation in the affinity sequence. Anions are selectively absorbed by moving to an already absorbed cation. The anion absorption selectivity order is based upon the solubility product (K_{sp}) of the anion/cation compound. For example, polymer saturated with Fe^{+3} strongly absorbs arsenate anion because ferric arsenate is highly insoluble.

The removal efficiency for transition-group heavy metals is about 90 percent at a flow rate of 0.1 bed volume per minute. The Sponge's highly porous nature speeds diffusional effects, promoting high rates of ion absorption. The Sponge can be used in columns, fishnet-type enclosures, or rotating drums. When used in a column, flow rates of three bed volumes per minute can be obtained at hydrostatic pressures only 2 feet above the bed and without additional pressurization. Therefore, sponge-packed columns are suitable for unattended field use (see photograph).

Absorbed ions can be eluted from the Sponge using techniques typically employed to regenerate ion exchange resins and activated carbons. Following elution, the Sponge can be used in the next absorption cycle. The number of useful cycles depends on the nature of the absorbed ions and the elution technique used. Alternatively, the metal-saturated Sponge can be incinerated. In some instances, the Sponge may be dried and reduced in volume to facilitate disposal. A



FORAGER® Sponge

The SITE Program assesses but does not approve or endorse technologies.

trailer-mounted pump-and-treat apparatus can handle up to 10 gallons per minute with low pumping pressures of 4 to 10 pounds per square inch. The apparatus employs 4 or 6 series connected plexiglas columns with valving to expedite regeneration and staging. Each column accommodates a fishnet container of Sponge. Groundwater can be remediated in situ using elongated fishnet bags that confine the Sponge. The bags are placed in well or trenches, and removed when saturated. Alternatively, the groundwater can be treated above ground in a packed column configuration.

WASTE APPLICABILITY:

The Sponge can scavenge metals in concentration levels of parts per million and parts per billion from industrial discharges, municipal sewage, process streams, and acid mine drainage waters.

STATUS:

This technology was accepted into the SITE Demonstration Program in June 1991. The FORAGER® Sponge was demonstrated in April 1994 at the National Lead Industry site in Pedricktown, New Jersey.

The Sponge has also effectively removed trace heavy metals from acid mine drainage water at three locations in Colorado. In bench-scale tests, the FORAGER® Sponge reduced mercury, lead, nickel, cadmium, and chromium in groundwater from various Superfund locations to below detectable levels. The FORAGER® Sponge was also demonstrated in a field-scale installation at a photoprocessing operation. The process achieved 75 percent reductions of chromate and silver at a cost of $1,100 per month.

DEMONSTRATION RESULTS:

Treatment performance from the SITE demonstration was as follows:

Analyte	Aver. Influ. Conc. (μg/l)	Percent Removal
Cadmium	537	90
Copper	917	97
Lead	578	97
Chromium^{III}	426	32

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The SITE Program assesses but does not approve or endorse technologies.

ECOVA CORPORATION
(Bioslurry Reactor)

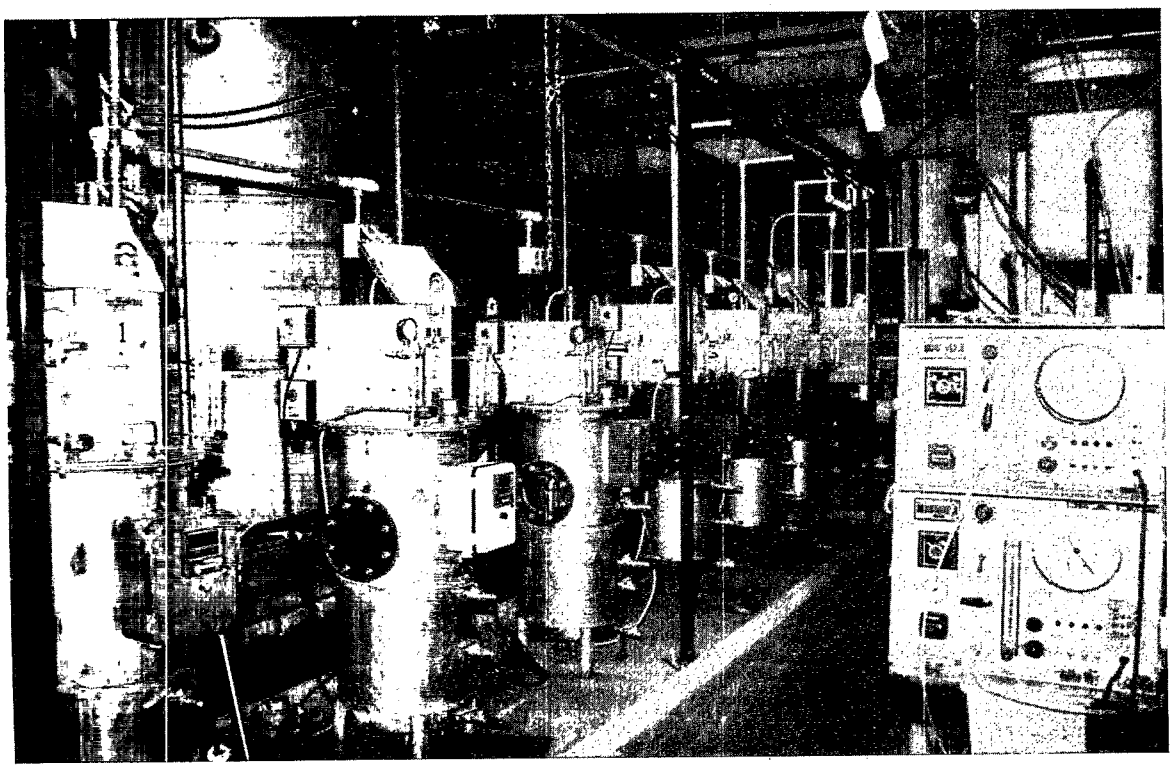
TECHNOLOGY DESCRIPTION:

ECOVA Corporation's slurry-phase bioremediation (bioslurry) technology aerobically biodegrades creosote-contaminated materials. The technology uses batch and continuous flow bioreactors to process polynuclear aromatic hydrocarbon (PAH)-contaminated soils, sediments, and sludges. The bioreactors are supplemented with oxygen, nutrients, and a specific inoculum of enriched indigenous microorganisms to enhance the degradation process.

Because site-specific environments influence biological treatment, all chemical, physical, and microbial factors are designed into the treatment process. The ultimate goal is to convert organic wastes into relatively harmless by-products of microbial metabolism, such as carbon dioxide, methane, and inorganic salts. Biological reaction rates are accelerated in a slurry system because of the increased contact efficiency between contaminants and microorganisms. The photograph below shows the bioslurry reactor.

WASTE APPLICABILITY:

Slurry-phase bioremediation can treat highly contaminated creosote wastes. It can also treat other concentrated contaminants that can be aerobically biodegraded, such as petroleum wastes. The bioslurry reactor system must be engineered to maintain parameters such as pH, temperature, and dissolved oxygen within ranges conducive to the desired microbial activity.



Bioslurry Reactor

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

ECOVA Corporation conducted bench- and pilot-scale studies to evaluate bioremediation of PAHs in creosote-contaminated soil from the Burlington Northern Superfund site in Brainerd, Minnesota. Bench-scale studies were conducted before pilot-scale evaluations to determine optimal treatment protocols. EIMCO Biolift slurry reactors were used for the pilot-scale processing. Data from the optimized pilot-scale program will be used to establish treatment standards for K001 wastes as part of EPA's Best Demonstrated Available Technology program.

This technology was accepted into the SITE Demonstration Program in spring 1991. From May through September 1991, EPA conducted a SITE demonstration using six bioslurry reactors at EPA's Test and Evaluation Facility in Cincinnati, Ohio.

DEMONSTRATION RESULTS:

Slurry-phase biological treatment significantly improved biodegradation rates of carcinogenic 4- to 6-ring PAHs. The pilot-scale bioslurry reactor reduced 82 $\pm$ 15 percent of the total soil-bound PAHs in the first week. After 14 days, total PAHs had been biodegraded by 96 $\pm$ 2 percent. An overall reduction of 97 $\pm$ 2 percent was observed over a 12-week treatment period, indicating that almost all biodegradation occurred within the first 2 weeks of treatment. Carcinogenic PAHs were biodegraded by 93 $\pm$ 3.2 percent to 501 $\pm$ 103 milligrams per kilogram (mg/kg) from levels of 5,081 $\pm$ 1,530 mg/kg.

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The SITE Program assesses but does not approve or endorse technologies.

ELI ECO LOGIC INTERNATIONAL INC.
(Gas-Phase Chemical Reduction Process)

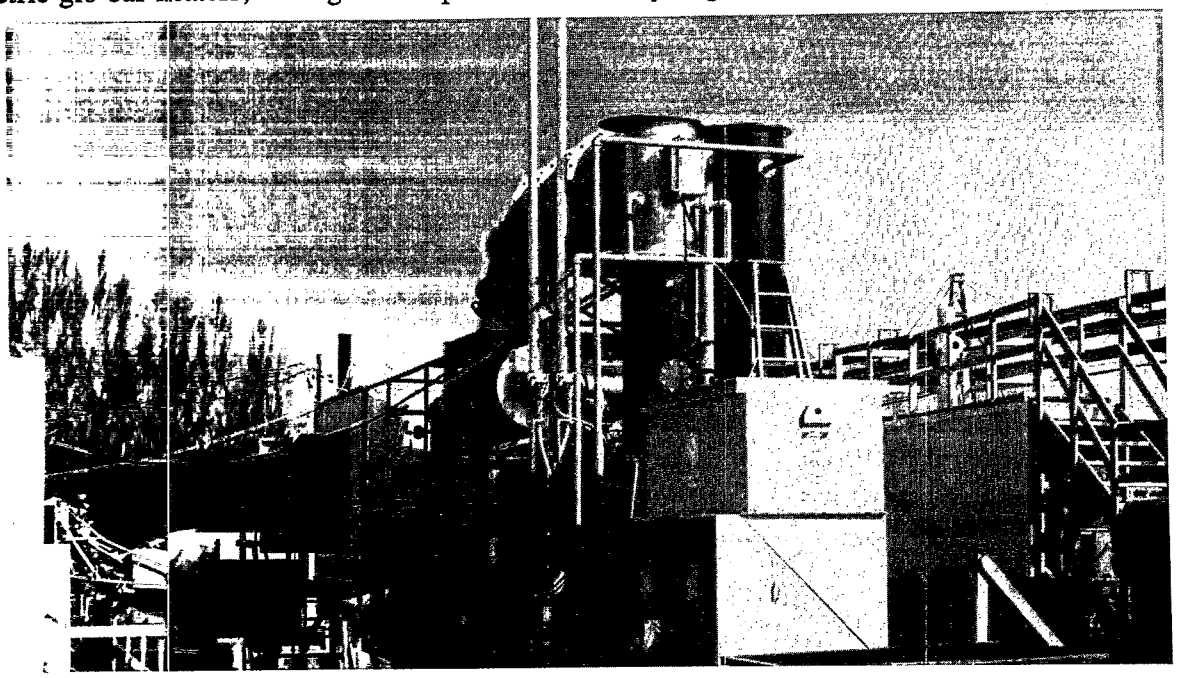
TECHNOLOGY DESCRIPTION:

The patented ELI Eco Logic International, Inc. (Eco Logic), process (see photograph below) uses a gas-phase reduction reaction of hydrogen with organic and chlorinated organic compounds at elevated temperatures to convert aqueous and oily hazardous contaminants into a hydrocarbon-rich gas product. After passing through a scrubber, the gas product's primary components are hydrogen, nitrogen, methane, carbon monoxide, water vapor, and other light hydrocarbons. Soils are handled within the thermal desorption unit (TDU), which is operated in conjunction with the reduction reactor. For further information on the TDU, see the profile in the Demonstration Program (Completed Projects Section).

The gas-phase reduction reaction takes place within a specially-designed reactor. Separate nozzles inject gaseous atomized waste, steam, and hydrogen into the reactor. As the mixture swirls down between the outer reactor wall and a central ceramic tube, it passes a series of electric glo-bar heaters, raising the temperature to 850 degrees Celsius. The reduction reaction takes place as the gases enter the ceramic tube through inlets at the bottom of the tube and travel up toward the scrubber. The scrubber removes hydrogen chloride, heat, water, and particulate matter. Scrubber liquid is treated as Resource Conservation and Recovery Act waste or recycled through the system for additional treatment.

When processing waste with a low organic content, approximately 95 percent of the hydrogen-rich gas recirculates to the reactor; the remaining 5 percent can be used as a supplementary fuel for a propane fired boiler that produces steam. Processing waste with a high organic content produces excess gas product, which can be compressed and stored for later analysis and reuse as supplementary fuel.

The unit is mounted on two standard, drop-deck, highway trailers. A computerized process control system allows the operator to monitor process variables such as temperature, pressure, hydrogen content, and oxygen levels. In addi-



Gas-Phase Chemical Reduction Process

The SITE Program assesses but does not approve or endorse technologies.

tion, an on-line mass spectrometer is used to monitor selected organic compounds.

WASTE APPLICABILITY:

The Eco Logic reactor is designed to treat aqueous and oily waste streams and soil contaminated with hazardous organic waste such as polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons, chlorinated dioxins and dibenzo-furans, chlorinated solvents, chlorobenzenes, and chlorophenols. Wastes with high water content can be easily handled by the process since water is a good source of hydrogen.

STATUS:

In October and November 1992, a SITE demonstration of the Eco Logic Process was conducted at the Middleground Landfill in Bay City, Michigan, under a Toxic Substances Control Act research and development permit. The test program was conducted in cooperation with Environment Canada and the Ontario Ministry of the Environment. The test was performed using PCB-contaminated wastewater and waste oil from the site.

Since this demonstration, Eco Logic has constructed a commercial-scale system (the SE25) which has a design capacity to treat 100-300 tons per day of contaminated soil or sediment and 20 tons per day of PCB liquid. The SE25 combines the reduction reactor, which treats PCB oils and aqueous wastes, with a redesigned TDU, which treats contaminated soils and sediments. The cost of processing these waste streams is estimated at $2,000 and $400 per ton, respectively. The first SE25 system has been exported to Australia where Works Approval has been granted by the Western Australia Environmental Protection Authority. Eco Logic was successful in winning 1.8 million Australian dollars in federal and state government funds for the destruction of 200 tons of obsolete pesticides. A second SE25 system will be constructed to serve the North American market, and will be ready for commercial use by the end of 1994.

DEMONSTRATION RESULTS:

During testing in Bay City, Michigan, the Eco Logic Process achieved the following results:

- At least 99.9999 percent destruction and removal efficiency for PCBs during all test runs
- A 99.99 percent destruction efficiency for perchloroethylene, a tracer compound, during all test runs
- Net destruction of trace feedstock dioxin and furan compounds during all test runs
- Throughput rates as follows, in tons per day:

	Nominal Design	Demonstrated Rate
Waste oil	4	2.3
Wastewater	10	7.0

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The SITE Program assesses but does not approve or endorse technologies.

ELI ECO LOGIC INTERNATIONAL, INC.
(Thermal Desorption Unit)

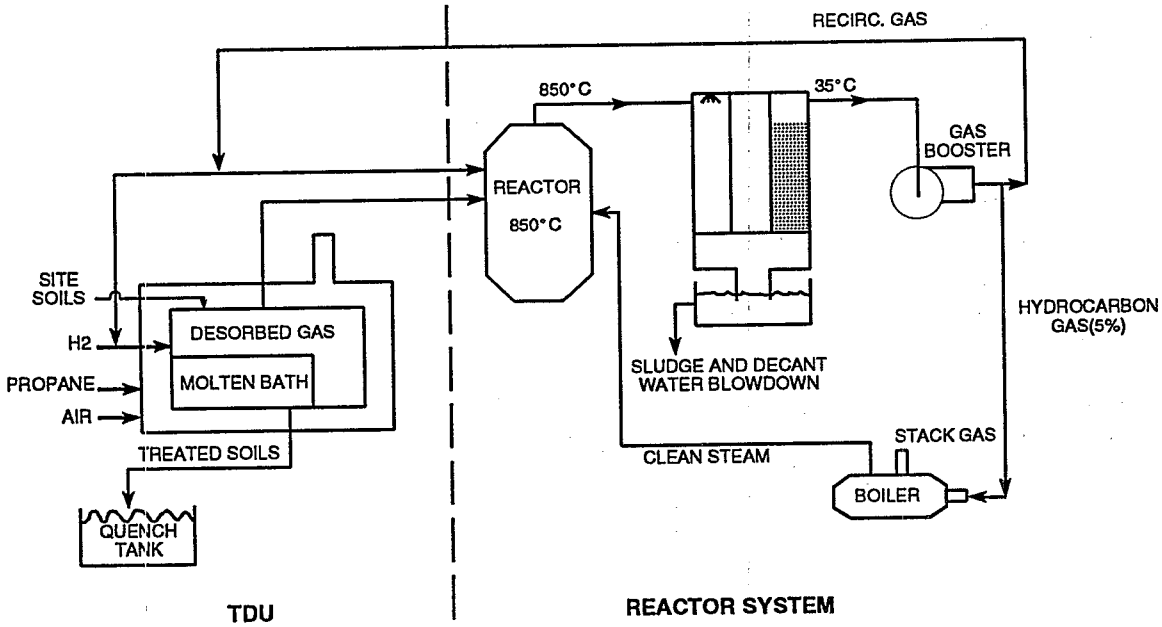
TECHNOLOGY DESCRIPTION:

ELI Eco Logic International, Inc.'s (Eco Logic), thermal desorption unit (TDU) is specially designed for use with Eco Logic's gas-phase chemical reduction reactor. For further information on the reduction reactor, see the profile in the Demonstration Program (Completed Projects Section).

The TDU consists of an externally-heated bath of molten tin metal (heated with propane) in a hydrogen gas atmosphere. Tin is used for several reasons: tin and hydrogen are non-reactive; tin's density allows soils to float on the molten bath; molten tin is a good fluid for heat transfer; tin is nontoxic in soil; and tin is used as a bath medium in the manufacture of plate glass.

Contaminated soil is conveyed into the TDU feed hopper, where an auger feeds the soil into the TDU. A screw feeder provides a gas seal between the outside air and the hydrogen atmosphere inside the TDU. The auger's variable speed drive provides feed rate control. Soil inside the TDU floats on top of the molten tin and is heated to 600 degrees Celsius, vaporizing the water and organic material. Decontaminated soil is removed from the tin bath into a water-filled quench tank. The water in the quench tank provides a gas seal between the TDU's hydrogen atmosphere and the outside air. A scraper mechanism removes desorbed soil from the quench tank into drums.

After desorption from the soil, the organic contaminants are carried from the TDU to Eco Logic's proprietary gas-phase reduction reactor. In the reactor, the organic contaminants undergo gas-phase chemical reduction reactions with hydrogen at elevated temperatures. This reaction converts organic and chlorinated organic contaminants into a hydrocarbon-rich gas product. After passing through a scrubber, the gas product's primary components are hydrogen, nitrogen, methane, carbon monoxide, water vapor, and other lighter hydrocarbons. Most of this gas product recirculates into the process, while excess gas can be used as supplemental



Schematic Diagram of the Thermal Desorption Unit

The SITE Program assesses but does not approve or endorse technologies.

fuel or compressed for later analysis and reuse as supplemental fuel. Refer to the profile of the Eco Logic gas-phase reduction process for a more complete description.

WASTE APPLICABILITY:

The Eco Logic TDU, when used with the gas-phase chemical reduction reactor, is designed to desorb soils and sludges contaminated with hazardous organic contaminants such as polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons, chlorinated dioxins and dibenzofurans, chlorinated solvents, chlorobenzenes, and chlorophenols. The combined technologies can easily handle wastes with high water content since water is a good source of hydrogen.

STATUS:

In October and November 1992, a SITE demonstration of the Eco Logic Process, including the TDU, was conducted at the Middleground Landfill in Bay City, Michigan, under a Toxic Substances Control Act research and development permit. The formal test program consisted of processing soil containing an average 627 parts per million (ppm) PCBs.

Further research and development over the last 18 months has focused on optimizing the process for commercial operations and improving the design of the soil/sediment processing unit. According to the vendor, the TDU design currently under construction has achieved excellent results in laboratory-scale tests, with soils and sediments desorbed from high ppm to percent levels down to low parts per billion levels.

A commercial-scale unit of the gas-phase chemical reduction process, combining the reductive reactor and TDU (SE-25), has been constructed with a design capacity of 100-300 tons per day of contaminated soil or sediment and 20 tons per day of PCB askarel fluid. The cost of processing these waste streams is estimated at $400 and $2,000 per ton, respectively. The first SE25 system has been exported to Australia for the destruction of 200 tons of obsolete pesticides. A second SE25 system will be ready for commercial use in North America by the end of 1994.

DEMONSTRATION RESULTS:

During testing in Bay City, Michigan, the Eco Logic TDU achieved the following:

- Destruction efficiencies (DE) for PCBs from the soil of 93.5 percent in run 1 and 98.8 percent in run 2.
- DE for hexachlorobenzene (a tracer com-pound) from the soil of 72.13 percent in run 1 and 99.998 percent in run 2.
- PCB destruction and removal efficiencies (DRE) for the combined TDU and reduction reactor system of 99.9999 percent for run 1 and 99.997 percent for run 2. PCB throughput for run 2 was below the target value, so a DRE of 99.9999 percent could not be achieved.

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The SITE Program assesses but does not approve or endorse technologies.

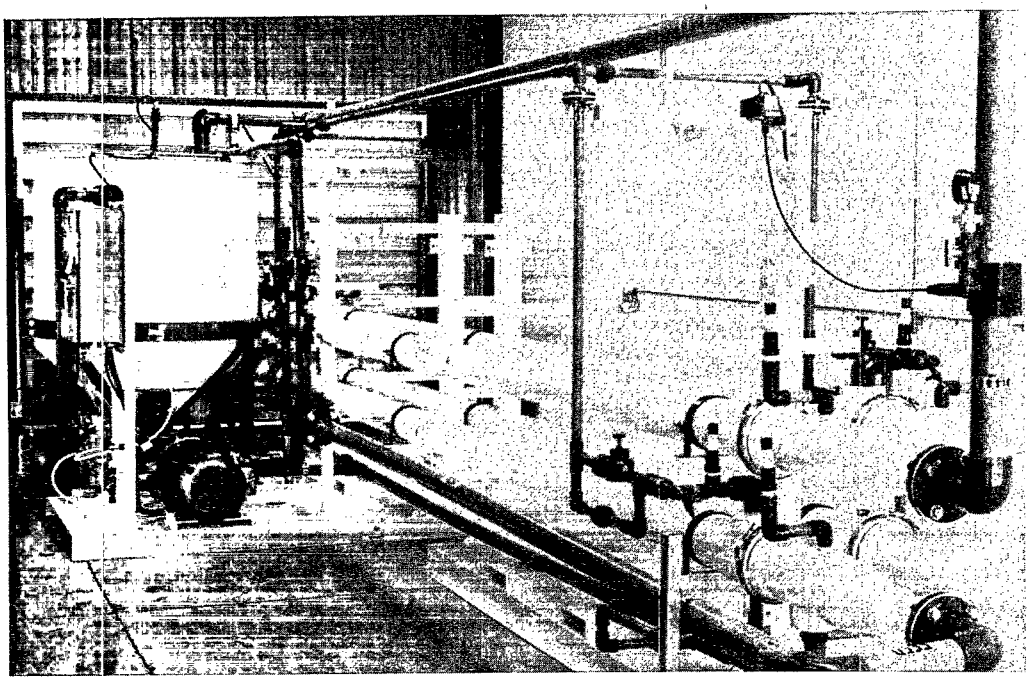
EPOC WATER, INC.
(Precipitation, Microfiltration, and Sludge Dewatering)

TECHNOLOGY DESCRIPTION:

The precipitation, microfiltration, and sludge dewatering treatment process uses a combination of processes to treat a variety of wastes. In the first step of the process, heavy metals are chemically precipitated. Precipitates and all particles larger than 0.2 micron are filtered through a unique tubular textile crossflow microfilter (EXXFLOW). The concentrate stream is then dewatered in an automatic tubular filter press of the same material (EXXPRESS).

EXXFLOW microfilter modules are fabricated from a proprietary tubular woven polyester. Wastes pumped into the polyester tubes form a dynamic membrane, which produces a high quality filtrate and removes all particle sizes larger than 0.2 micron. The flow velocity continually maintains the membrane, maximizing treatment efficiency.

Metals are removed via precipitation by adjusting the pH in the EXXFLOW feed tank. Metal hydroxides or oxides form a dynamic membrane with any other suspended solids. The EXXFLOW concentrate stream, which contains up to 5 percent solids, enters the EXXPRESS modules with the discharge valve closed. A semidry cake, up to 0.25 inch thick, is formed inside the tubular filter. When the discharge valve is opened, rollers on the outside of the tubes move to form a venturi within the tubes. The venturi creates an area of high velocity within the tubes, which aggressively cleans the cloth and discharges the cake in chip form onto a wedge wire screen. Discharge water is recycled to the feed tank. EXXPRESS filter cakes are typically 40 to 60 percent solids by weight. Other constituents can be removed using seeded slurry methods in EXXFLOW. Hardness can be removed by using lime. Oil and grease can be removed by adding adsorbents. Nonvolatile



EXXFLOW/EXXPRESS Demonstration Unit

The SITE Program assesses but does not approve or endorse technologies.

organics and solvents can be removed using adsorbents, activated carbon or powdered ion-exchange results. If the raw feed contains a high percentage of solids, EXXPRESS can be used first, with EXXFLOW acting as a final polish for the product water.

The EXXFLOW/EXXPRESS demonstration unit is transportable and is mounted on skids. The unit is designed to process approximately 30 pounds of solids per hour and 10 gallons of wastewater per minute.

WASTE APPLICABILITY:

The EXXFLOW and EXXPRESS technologies have treated water containing heavy metals, silica, pesticides, ink, oil and grease, bacteria, suspended solids, and constituents that can be precipitated to particle sizes greater than 0.1 micron. The EXXPRESS system can handle waste streams containing up to 5 percent solids to produce a semidry cake of 40 to 60 percent solids by weight. Nonvolatile organics and solvents can also be removed from the water by adding powdered adsorbents.

Soils and sludge can be decontaminated through acid leaching of the metals, followed by precipitation and microfiltration. Lime and alum sludges from municipal, industrial, and power plant clarifiers can also be treated.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1989. Bench-scale tests were conducted in 1990. The SITE demonstration was conducted during May and June 1992 on highly acidic mine drainage from the Old Number 8 mine seep at the Iron Mountain Superfund site in Redding, California. The system was successful in removing heavy metals. In most cases, the system used sodium hydroxide, lime, or magnesium oxide as the precipitating chemicals to produce no detectable concentrations of metals in the treated water samples. Reports will be available in 1995.

This technology was commercialized in 1988. Treatment systems have since been installed at over 45 sites worldwide. System capacities range from 1 gallon per minute to over 2 million gallons per day.

Developer claims for metal removals on Old Number 8, when neutralizing with NaOH and $Ca(OH)_2$, were generally met or exceeded except for aluminum. This was most likely due to the difficulty encountered when using NaOH and $Ca(OH)_2$ to control the pH of this waste stream. The claims for all metals, including aluminum, were exceeded when MgO was used as the neutralizing agent. In most cases, there were no detectable concentrations of heavy metals in the permeate samples.

Filter cake produced from the demonstration test contained approximately 12 percent, 31 percent, and 30 percent solids when NaOH, $Ca(OH)_2$, and MgO were used as the treatment chemicals, respectively. Toxicity characteristic leaching procedure (TCLP) leaching tests performed on the filter cake showed that leachable levels of TCLP metals were below the regulatory limits for each of the treatment chemicals tested.

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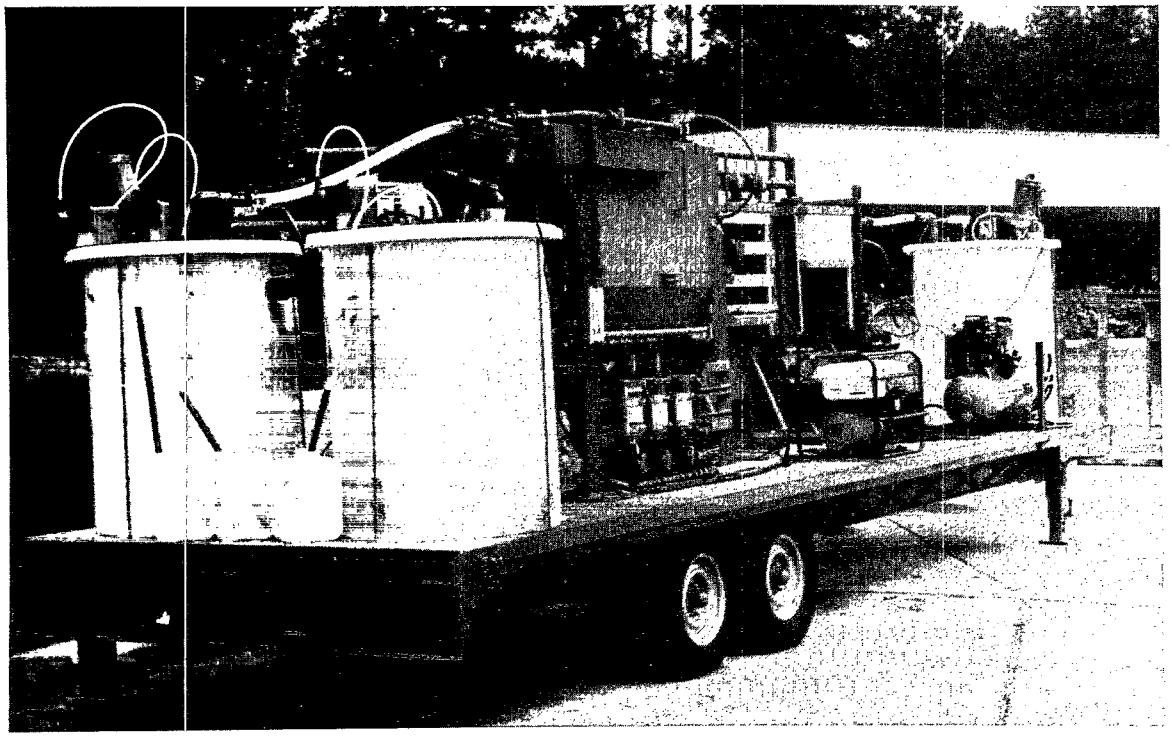
The SITE Program assesses but does not approve or endorse technologies.

FILTER FLOW TECHNOLOGY, INC.
(Heavy Metals and Radionuclide Polishing Filter)

TECHNOLOGY DESCRIPTION:

The colloid polishing filter method (CPFM) uses an inorganic, oxide-based compound of granular pellets (Filter Flow 1000) to remove colloidal and ionic form heavy metals and nontritium radionuclides from water. Contaminants are removed through a combination of sorption, chemical complexing, and filtration. The CPFM effectively removes inorganic metallic pollutants from groundwater or wastewater, and can be used independently or subsequent to flocculation and bulk solids removal.

The primary treatment and CPFM process involves five basic steps. If necessary, contaminated water is first pumped to an influent mixing tank for chemical preconditioning (pH adjustment or sodium sulfide addition) to induce formation of colloidal forms of pollutants. Second, suspended solids are removed by an incline plate mini-clarifier or filter. Next, microparticles are removed using overflow water. The low solids then pass through to the colloid filter press units, where heavy metals and radionuclides are removed by the sorption, chemical complexing, and filtration effects of Filter Flow 1000. Finally, the pH of treated water exiting the colloid filters is adjusted prior to discharge. Following treatment, sludge in the miniclarifier is dewatered. The filter packs are dewatered with compressed air to form a cake containing 60 to 70 percent solids. These two solid wastes may be combined for disposal. Optional single-use, disposable, and reusable bed material designs have been developed, with emphasis on easy, safe handling and removal of the spent filter pack material. Both batch (up to 10,000 gallons per run) and continuous (5 to 100 gallons per minute) treatment systems have been designed for application in both mobile field equipment and fixed installations.



Mobile Colloid Filter Unit, Including Mixing Tanks, Pumps, Filter Apparatus, and Other Equipment

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The CPFM efficiently removes heavy metals and nontritium radionuclides from water to parts per million or parts per billion levels. This simple methodology can be used separately to treat water with low total suspended solids; in a treatment train downstream from other technologies such as soil washing, organic oxidation, or as a conventional wastewater treatment that uses flocculation and solids removal.

The CPFM's major advantage is high performance and lower cost to treat a wide range of inorganic metallic pollutants in water, including monovalent and divalent forms, multivalent and high valence forms existing as colloids, and ionic, chelated, and complexed forms. The same equipment can treat water at different sites, but the preconditioning chemistry and pH must be optimized for each site from bench and field test results.

STATUS:

This technology was accepted into the SITE Demonstration Program in July 1991. EPA and the U.S. Department of Energy (DOE) co-sponsored the technology evaluation. The SITE demonstration occurred at DOE's Rocky Flats Plant (RFP), Denver, Colorado, in September 1993 under a cooperative understanding between EPA and DOE. The Demonstration Bulletin (EPA/540/MR-94/501) and Capsule Report (EPA/540/R-94/501a) are available from EPA.

DEMONSTRATION RESULTS:

The CPFM treated about 10,000 gallons of water that contained about 100 milligrams per liter of uranium and 100 picoCuries per liter of gross alpha-contaminated groundwater. The demonstration was comprised of three tests. The first test consisted of three runs of 4 hours each, treating about 5 gallons per minute (gpm). For the second test, also run for 4 hours at 5 gpm, the influent water was pre-treated with sodium sulfide. The third test was a 15-hour run designed to determine the amount of contamination each filter pack could treat.

The CPFM system removed up to 95 percent uranium and 94 percent gross alpha contamination. However, due to the significant variation in removal efficiencies between runs, average removal efficiencies were significantly less: 80 percent for uranium, and 72 percent for gross alpha. Though removal is largely attributable to the colloid filter pack, uranium was significantly removed in runs 1 and 4 before the colloid filter unit. Significant gross alpha was also removed before colloid filter treatment in runs 1 and 3. At less than the maximum removal efficiency, effluent from the CPFM system did not meet the extremely strict Colorado Water Quality Control Commission standards for discharge of waters from RFP.

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The SITE Program assesses but does not approve or endorse technologies.

FUNDERBURK & ASSOCIATES
(formerly HAZCON, INC.)
(Dechlorination and Immobilization)

TECHNOLOGY DESCRIPTION:

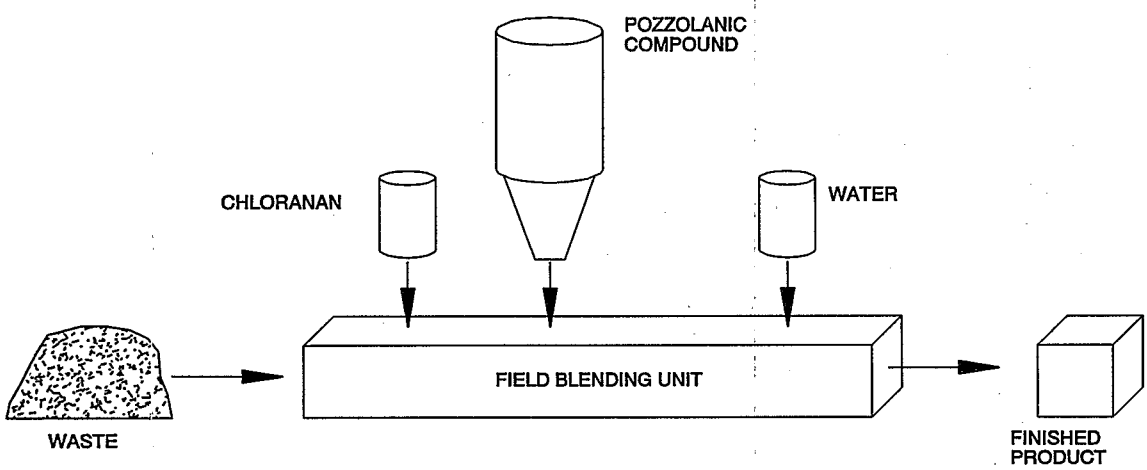
This technology mixes hazardous wastes with cement (or fly ash), water, and one of 18 patented reagents commonly known as "Chloranan" to immobilize heavy metals. The developers also claim that certain chlorinated organics are dechlorinated by the treatment reagents.

Soils, sludges, and sediments can be treated in situ or excavated and treated ex situ. Sediments can be treated under water. Treatment occurs in batches, with volumetric throughput rated at 120 tons per hour. In the finished product, metals are fixed to a very low solubility point.

The treatment process begins by adding Chloranan and water to the blending unit (see figure below). Waste is then added and mixed for 2 minutes. Cement or fly ash is added and mixed for a similar time. After 12 hours, the treated material hardens into a concrete-like mass that exhibits unconfined compressive strengths (UCS) ranging from 1,000 to 3,000 pounds per square inch (psi), with permeabilities of 10^{-9} centimeters per second (cm/sec). The hardened concrete-like mass can withstand several hundred freeze and thaw cycles.

WASTE APPLICABILITY:

The technology is applicable to wastes containing heavy metals and organics. The developers claim that the technology has been refined since the 1987 SITE demonstration and can now dechlorinate certain chlorinated organics as well as immobilize other wastes, including those with high levels of metals. The wastes with organic and inorganic contaminants can be treated separately or together with no impact on the chemistry of the process. The process can treat contaminated material with high concentrations (up to 25 percent) of oil.



Dechlorination and Immobilization Treatment Process

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

This technology was demonstrated in October 1987 at a former oil processing plant in Douglassville, Pennsylvania. The site soil contained high levels of oil and grease (250,000 parts per million [ppm]) and heavy metals (22,000 ppm lead), and low levels of volatile organic compounds (VOC) (100 ppm) and polychlorinated biphenyls (PCB) at 75 ppm. An Applications Analysis Report (EPA/540/A5-89/001) and a Technology Evaluation Report (EPA/540/5-89/001a) are available. A report on long-term monitoring may be obtained from EPA's Risk Reduction Engineering Laboratory. The technology has also been used to remediate a California Superfund site with zinc contamination as high as 220,000 ppm.

Since the demonstration in 1987, the technology has been enhanced through the development of 17 additional reagent formulations that are claimed to dechlorinate many chlorinated organics, including PCBs, ethylene dichloride, trichloroethene, and pentachlorophenol.

This technology is no longer available through a vendor. Contact the EPA Project Manager for further information.

DEMONSTRATION RESULTS:

Samples were taken after treatment at intervals of 7 days, 28 days, 9 months, and 22 months. Analytical results from these samples were generally favorable. The physical test results were good, with UCS between 220 and 1,570 psi. Very low permeabilities (10^{-9} cm/sec) were recorded, and the porosity of the treated wastes was moderate. Durability test results showed no change in physical strength after the wet and dry and freeze and thaw cycles. The waste volume increased by about 120 percent. However, refinements of the technology now restrict volumetric increases to the 15 to 25 percent range. Using a smaller volume of additives reduces physical strength, but toxicity reduction is not affected. Data obtained since the 1987 SITE demonstration indicate that one or more of the reagents used in immobilizing heavy metals may be able to dechlorinate certain hazardous organics such as PCBs.

The results of the leaching tests were mixed. The toxicity characteristic leaching procedure (TCLP) results of the stabilized wastes were very low; essentially, concentrations of metals, VOCs, and semivolatile organic compounds (SVOC) were below 1 ppm. Lead leachate concentrations decreased by a factor of 200 to below 100 parts per billion. VOC and SVOC concentrations in the TCLP leachate were not affected by treatment. Oil and grease concentrations were greater in the treated waste TCLP leachate (4 ppm) than in the untreated waste TCLP leachate (less than 2 ppm). The physical properties of the treated waste include high UCS, low permeabilities, and good weathering properties.

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The SITE Program assesses but does not approve or endorse technologies.

GENERAL ATOMICS
(Circulating Bed Combustor)

TECHNOLOGY DESCRIPTION:

General Atomics' circulating bed combustor (CBC) uses high velocity air to entrain circulating solids and create a highly turbulent combustion zone that destroys toxic hydrocarbons. The commercial-size, 36-inch combustion chamber can treat up to 150 tons of contaminated soil daily, depending on the heating value of the feed material.

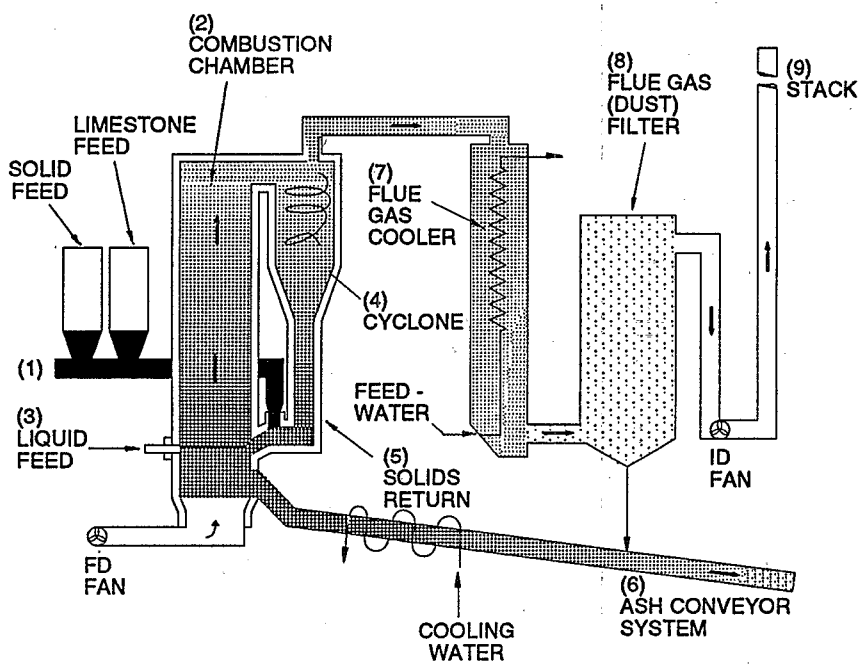
The CBC operates at relatively low temperatures (1,450 to 1,600 degrees Fahrenheit [°F]), reducing operating costs and potential emissions of such gases as nitrogen oxide (NO_x) and carbon monoxide (CO). Auxiliary fuel can be natural gas, fuel oil, or diesel. No auxiliary fuel is needed for waste streams with a net heating value greater than 2,900 British thermal units per pound.

The CBC's high turbulence produces a uniform temperature around the combustion chamber and hot cyclone. The CBC also completely mixes the waste material during combustion. Effective mixing and relatively low combustion temperature also reduce emissions of NO_x and CO.

As shown in the figure below, waste material and limestone are fed into the combustion chamber along with the recirculating bed material from the hot cyclone. The limestone neutralizes acid gases. A conveyor transports the treated ash out of the system for proper disposal. Hot combustion gases pass through a convective gas cooler and baghouse before they are released to the atmosphere.

WASTE APPLICABILITY:

The CBC process can treat liquids, slurries, solids, and sludges contaminated with corrosives, cyanides, dioxins and furans, inorganics, metals, organics, oxidizers, pesticides, polychlorinated biphenyls (PCB), phenols, and volatiles. Applications include industrial wastes from refineries, ammunition and chemical plants, manufacturing sites, and military sites. The CBC is permitted under the Toxic Substance Control Act to burn PCBs in all 10 EPA re-



Circulating Bed Combustor (CBC)

The SITE Program assesses but does not approve or endorse technologies.

gions, having demonstrated a 99.9999 percent destruction removal efficiency (DRE).

Waste feed for the CBC must be sized to less than 1 inch. Metals in the waste do not inhibit performance, and become less leachable after incineration. Treated residual ash can be replaced on site or stabilized for landfill disposal if metals exceed regulatory limits.

STATUS:

The circulating bed combustor (formerly owned by Ogden Environmental Services) was accepted into the SITE Demonstration Program in March 1989. A treatability study and demonstration on wastes from the McColl Superfund site in California was conducted under the guidance of the SITE Program, EPA Region 9, and the California Department of Health Services. The pilot-scale demonstration was conducted at General Atomics' Research Facility in San Diego, California, using a 16-inch-diameter CBC.

Several 36-inch-diameter CBCs have been built and successfully operated. At the Swanson River project in Alaska, over 100,000 tons of PCB-contaminated soil were successfully treated to limits of detectability that were far below allowable limits. The process took just over three years from mobilization of the transportable unit to demobilization. The plant operated at over 85 percent availability all year, including the winter, when temperatures were below minus 50 °F. The soil was delisted and returned to the original site. The unit has subsequently been moved to a Canadian site.

Another unit of similar size treated soils contaminated with #6 fuel oil. Over 14,000 tons of soil were successfully treated and delisted. Upon completion, the site was upgraded to permit operation as a merchant facility treating a wide range of LUFT materials from other sites. Two other units of the same size are under construction in Germany for treatment of munitions wastes consisting of slurried explosives and propellant. These units will be operational in fall 1994, and they have been permitted under stringent German regulations.

DEMONSTRATION RESULTS:

The demonstration successfully achieved the following goals:

- Achieved DRE values of 99.99 percent or greater for principal organic hazardous constituents
- Minimized formation of products of incomplete combustion
- Met Research Facility permit conditions and California South Coast Basin emission standards
- Controlled sulfur oxide emissions by adding limestone and residual materials (fly ash and bed ash); these emissions were nonhazardous. No significant levels of hazardous organic compounds were found in the system, the stack gas, or in the bed and fly ash. The CBC minimized emissions of sulfur oxide, NO_x, and particulates. Other regulated pollutants were controlled to well below permit levels.

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The SITE Program assesses but does not approve or endorse technologies.

GEO-CON, INC.
(In Situ Solidification and Stabilization Process)

TECHNOLOGY DESCRIPTION:

The in situ solidification and stabilization process technology immobilizes organic and inorganic compounds in wet or dry soils, using reagents (additives) to produce a cement-like mass. The basic components of this technology are: 1) Geo-Con, Inc.'s (GEO-CON), deep soil mixing system (DSM), to deliver and mix the chemicals with the soil in situ; and 2) a batch mixing plant to supply International Waste Technologies' (IWT) proprietary additives (see figure below).

The proprietary additives generate a complex, crystalline, connective network of inorganic polymers in a two-phase reaction. In the first phase, contaminants are complexed in a fast-acting reaction. In the second phase, macromolecules build over a long period of time in a slow-acting reaction.

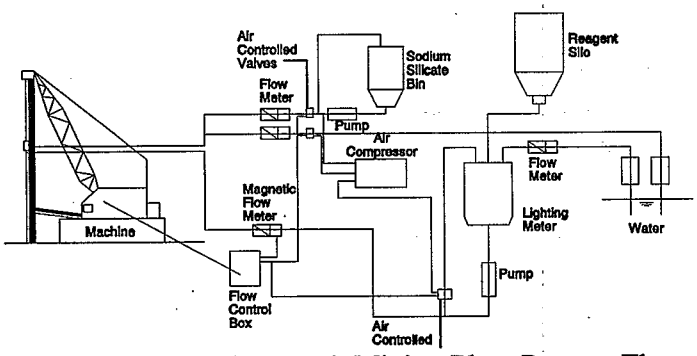
The DSM system involves mechanical mixing and injection. The system consists of one set of cutting blades and two sets of mixing blades attached to a vertical drive auger, which rotates at approximately 15 revolutions per minute. Two conduits in the auger inject the additive slurry and supplemental water. Additives are injected on the downstroke; the slurry is further mixed upon auger withdrawal. The treated soil columns are 36 inches in diameter and are positioned in an overlapping pattern of alternating primary and secondary soil columns.

WASTE APPLICABILITY:

The in situ solidification and stabilization process treats soils, sediments, and sludge-pond bottoms contaminated with organic compounds and metals. The process has been laboratory-tested on soils containing polychlorinated biphenyls (PCB), pentachlorophenol, refinery wastes, and chlorinated and nitrated hydrocarbons. The process can treat any waste for which a physical or chemical reagent is applicable.

STATUS:

A SITE demonstration, using one-auger, was conducted at the General Electric Service Shop site in Hialeah, Florida in April 1988. Two 10-by-20-foot areas were treated - one to a depth of 18 feet, and the other to a depth of 14 feet. Ten months after the demonstration, long-term monitoring tests were performed on the treated sectors. The Technology Evaluation Report (EPA/540/5-89/004a) and the Applications Analysis Report (EPA/540/A5-89/004) have been published. A four-auger process remediated the PCB-contaminated Hialeah site during the winter and spring of 1990. Geo-Con has used the process to complete over 40 in situ stabilization projects throughout the United States. Several significant projects completed to date include:



In Situ Solidification Batch Mixing Plant Process Flow

The SITE Program assesses but does not approve or endorse technologies.

- Construction of a 110,000 square foot, 60-feet deep soil-bentonite DSM wall to contain contaminated groundwater from a former waste pond. All DSM permeabilities were less than 10^{-7} centimeters per second, a first for DSM construction
- Shallow soil mixing and stabilization of 82,000 cubic yards of contaminated soils at a former manufactured gas plant site that was ultimately converted to a city park

The equipment has been scaled up to diameters as large as 12 feet. Typical process costs are $40 to $50 per cubic yard plus reagent costs. To date, Geo-Con has utilized this process to treat over one million cubic yards of contaminated soils and sludges.

DEMONSTRATION RESULTS:

The SITE demonstration yielded the following results:

- PCB immobilization appeared likely, but could not be confirmed because of low PCB concentrations in the untreated soil. Leachate tests on treated and untreated soil samples showed mostly undetectable PCB levels. Leachate tests performed 1 year later on treated soil samples showed no increase in PCB concentrations, indicating immobilization.
- Sufficient data were unavailable to evaluate the system's performance on metals or other organic compounds.
- Each of the test samples showed high unconfined compressive strength (UCS), low permeability, and low porosity. These physical properties improved when retested one year later, indicating the potential for long-term durability.
- The soil's bulk density increased 21 percent after treatment. This treatment increased the treated soil volume by 8.5 percent and caused a small ground rise of 1 inch per foot of treated soil.
- The UCS of treated soil was satisfactory, with values up to 1,500 pounds per square inch.
- The treated soil's permeability was satisfactory, decreasing to 10^{-6} and 10^{-7} centimeters per second (cps) compared to 10^{-2} cps for untreated soil.
- The wet and dry weathering test on treated soil was satisfactory.
- Data provided by Geo-Con indicated some immobilization of volatile and semivolatile organics, which may be due to organophilic clays present in the reagent. Data are insufficient to confirm this immobilization.
- Performance data are limited outside of the SITE Program. Geo-Con modifies the binding agent for different wastes. Treatability studies should be performed for specific wastes.
- Process costs were $194 per ton for the 1-auger machine used in the demonstration, and $111 per ton for a commercial 4-auger operation. More recent experience with larger scale equipment reduced process costs to about $140 per cubic yard.

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The SITE Program assesses but does not approve or endorse technologies.

GEOSAFE CORPORATION
(In Situ Vitrification)

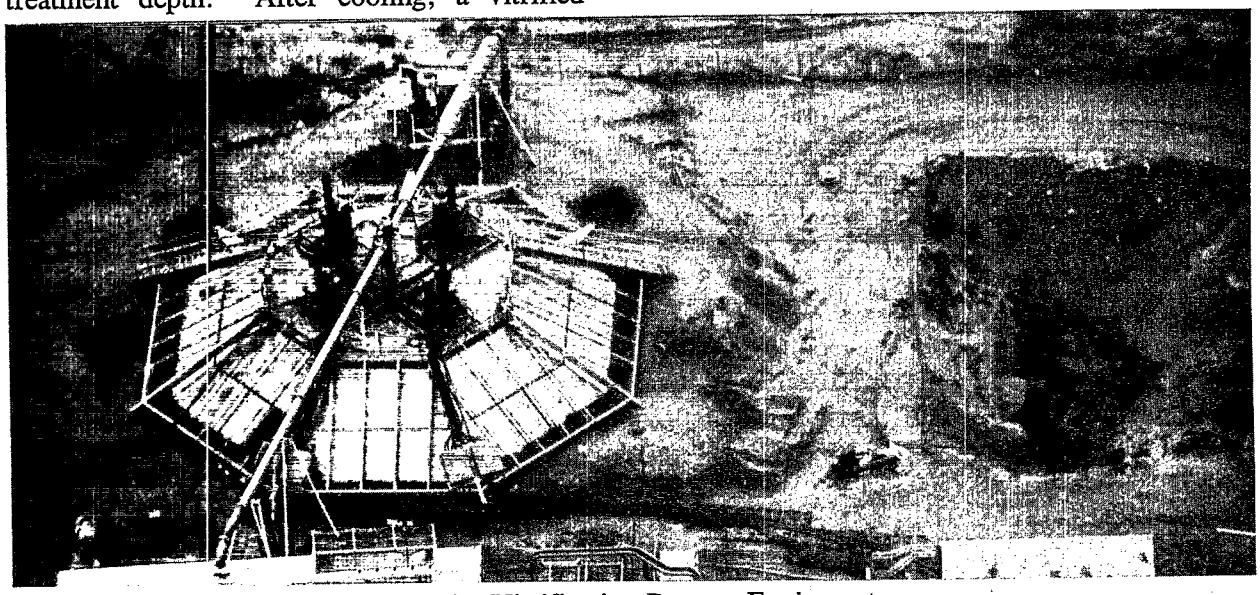
TECHNOLOGY DESCRIPTION:

In situ vitrification (ISV) uses an electric current to melt soil or other earthen materials at high temperatures ranging from 1,600 to 2,000 degrees Celsius (°C), destroying organic pollutants by pyrolysis. Inorganic pollutants are incorporated within the vitrified glass and crystalline mass. Water vapor and organic pyrolysis products are captured in a hood, which draws the off-gases into a treatment system that removes particulates and other pollutants.

To begin the vitrification process, an array of four large electrodes is inserted into contaminated zones containing enough soil for melting to occur (see photograph below). Because soil typically has low electrical conductivity until molten, flaked graphite and glass frit are placed on the soil surface between the electrodes to provide a starter path for the electric current. The electric current passes through the starter path and melts the soil at the surface. As power is applied, the melt continues downward and outward at an average rate of 1 to 2 inches per hour. The electrode array is lowered progressively, as the melt grows, to the desired treatment depth. After cooling, a vitrified monolith remains, with a glass and microcrystalline structure. This monolith possesses high strength and excellent weathering and leaching properties. The large-scale ISV system melts soil at a rate of 4 to 6 tons per hour.

Air flow through the hood is controlled to maintain a negative pressure. Excess oxygen is supplied for combustion of any organic pyrolysis by-products. Off-gases are treated by quenching, pH-controlled scrubbing, dewatering (mist elimination), heating (for dew point control), particulate filtration, and activated carbon adsorption. Thermal oxidation may be employed as a final off-gas polishing stage in place of carbon adsorption.

Individual melt settings (each single placement of electrodes) may encompass a total melt mass of up to 1,400 tons and a maximum width of 40 feet. Single-setting depths as great as 22 feet below ground surface have been achieved. Special settings to reach deeper contamination are also possible. The void volume in earthen materials (30 to 50 percent for typical soils) and volatile materials are removed during processing, greatly reducing the waste volume.



In Situ Vitrification Process Equipment

The SITE Program assesses but does not approve or endorse technologies.

The mobile ISV system is mounted on three semi-trailers. Electric power is usually obtained from a utility distribution system at transmission voltages of 12.5 or 13.8 kilovolts. Typical power consumption ranges from 800 to 1,000 kilowatt-hours per ton of processed soil. A diesel generator may also provide power on site. The electrical supply system has an isolated ground circuit to provide safety.

WASTE APPLICABILITY:

The ISV process can destroy or remove organics and immobilize most inorganics in contaminated soils, sediments, sludges, or other earthen materials. The process has been tested on a broad range of volatile and semivolatile organic compounds, other organics including dioxins and polychlorinated biphenyls (PCB), and on most priority pollutant metals and heavy metal radionuclides.

In wet soils or sludges, water is driven off at the 100 °C isotherm moving in advance of the melt. Water removal increases energy consumption and associated costs. Also, sludges must contain enough glass-forming material (nonvolatile, nondestructible solids) to produce a molten mass that will destroy or remove organic pollutants and immobilize inorganic pollutants. Most natural soils can be processed without modification. In isolated cases, fluxing materials may be necessary to obtain the desired electrical conductivity.

The effectiveness of the large-scale ISV process is limited by 1) individual void volumes in excess of 150 cubic feet, 2) rubble exceeding 20 percent by weight, and 3) combustible organics in the soil or sludge exceeding 5 to 10 percent by weight, depending on the heating value. Contaminant processing below the water table may require some means to limit recharge. Site adaptions and/or process and equipment modification can be made to accommodate site conditions exceeding these limitations if desired.

STATUS:

The SITE demonstration of this technology occurred during March and April 1994 at the former Parsons Chemical site (Parsons). Parsons is a Superfund site in Grand Ledge, Michigan, where the soil is contaminated with pesticides, metals, and low levels of dioxins and furans. A Demonstration Bulletin (EPA/540/MR-94/520) is available from EPA. The Innovative Technology Evaluation Report will be available in 1995.

The ISV has treated a broad range of hazardous, radioactive, and mixed wastes, and over 30 different soil types from the United States, Canada, Japan, and Australia. The U.S. Department of Energy (DOE) Pacific Northwest Laboratory continues to research and develop the technology, including an upcoming large-scale treatability test on a radioactive liquid waste seepage pit at Oak Ridge, Tennessee. Geosafe recently completed a 3,100-ton Toxic Substance Control Act (TSCA) demonstration project on soils contaminated with PCBs up to 12,000 parts per million in support of its application for a National TSCA Operating Permit.

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The SITE Program assesses but does not approve or endorse technologies.

GIS/SOLUTIONS, INC.
(GIS/Key™ Environmental Data Management System)

TECHNOLOGY DESCRIPTION:

GIS/Key™ is a comprehensive environmental database management system that integrates site data and graphics, enabling the user to create geologic cross-sections, boring logs, potentiometric maps, isopleth maps, structure maps, summary tables, hydrographs, chemical time series graphs, and numerous other maps and line graphs. The software is menu-driven, making it relatively simple to use. All system outputs meet Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) reporting requirements and are consistent with current industry practices.

GIS/Key™ can be a cost-effective tool to help manage hazardous waste site environmental data more effectively and accurately. GIS/Key™ allows project managers to focus on problem solving, because less time is required to enter, evaluate, and report the supporting site data. It also provides project managers access to environmental databases traditionally available only to computer specialists.

WASTE APPLICABILITY:

The GIS/Key™ software can be used at any Superfund site to facilitate the collection, reporting, and analysis of site data. The software is designed with numerous checks to assure the quality of the data, including comprehensive quality assurance/quality control protocols. System outputs, listed in the table below, are presentation-quality and meet RCRA and CERCLA reporting requirements. With an electronic laboratory delivery ,GIS/Key™ can immediately show where the samples fall outside of historical data ranges along with federal, state, and local action levels.

STATUS:

The GIS/Key™ software is in use at two Superfund sites: the Crazyhorse site near Salinas, California, and the Moffett Field site near San Jose, California.

This technology was accepted into the SITE Demonstration Program in summer 1992. The demonstration was held in August 1993 in San

CHEMISTRY	GEOLOGY	HYDROLOGY
• Isopleth maps of soil or water quality plan or section view • Graphs - Time series graphs - Chemical versus chemical and inter-well and intra-well - Concentration versus distance - Summary of statistics • Trilinear Piper diagrams • User alerts - When QA/QC results fall outside data quality objectives - When sample results fall outside historical ranges - When sample results exceed applicable regulatory standards • Presentation-quality data tables	• Completely customizable boring logs • Geologic cross-section maps • Isopach maps • Structure maps • Modflow integration	• Density-corrected water level, floating product, hydraulic conductivity, and contour maps • Water elevation and floating product thickness versus time graphs • Flow versus time and chemical flux graphs • Modflow integration

Environmental Data Management System Outputs

The SITE Program assesses but does not approve or endorse technologies.

Francisco, California, and December 1993 in Washington, D.C. The Demonstration Bulletin (EPA/540/MR-94/505), SITE Technology Capsule (EPA/540/SR-94/505), and Innovative Technology Evaluation Report (EPA/540/R-94/505) are available from EPA.

The U.S. Air Force's Environmental Data Management and Decision Support working group is testing the effectiveness of the GIS/Key™ technology at Norton Air Force Base. The technology is also being used by consultants at over 20 other U.S. Air Force bases.

GIS/Solutions has developed a three-dimensional visualization system that minimizes the number of sampling locations required to lower maximum uncertainty and assess the optimal location for additional monitoring wells, if needed.

A client server version of GIS/Key™ is available.

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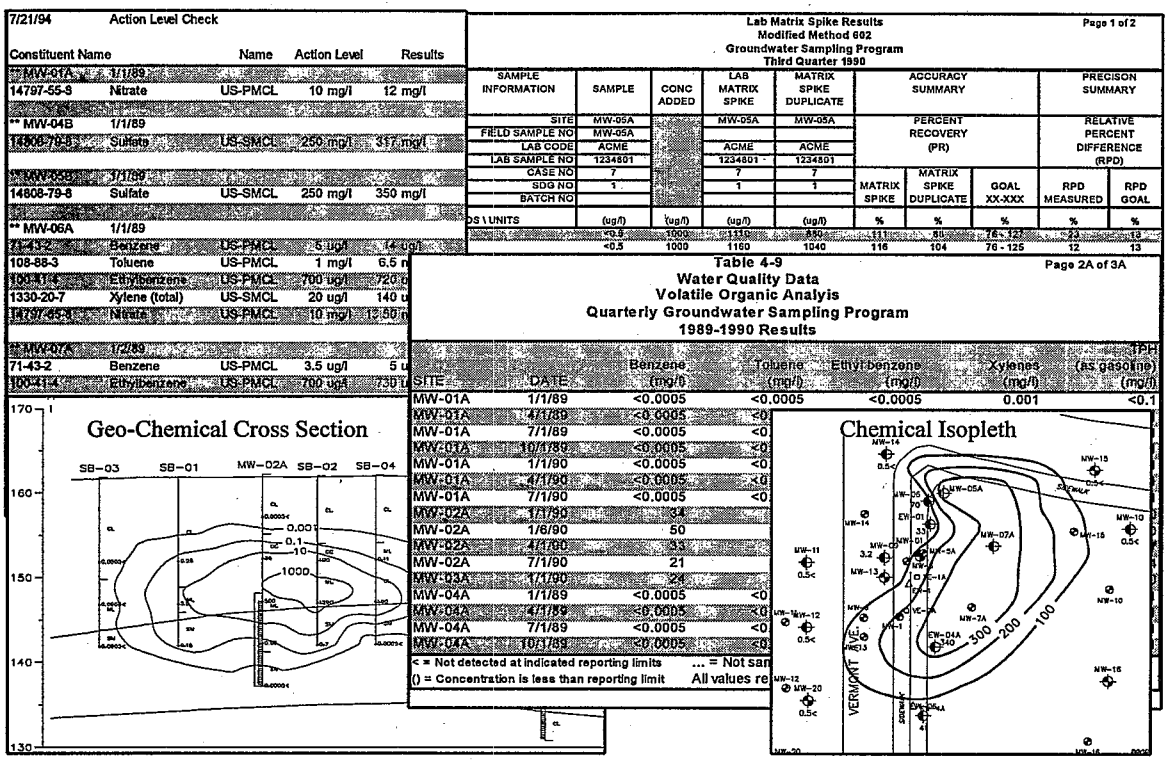


Examples of GIS/Key™ Work Products

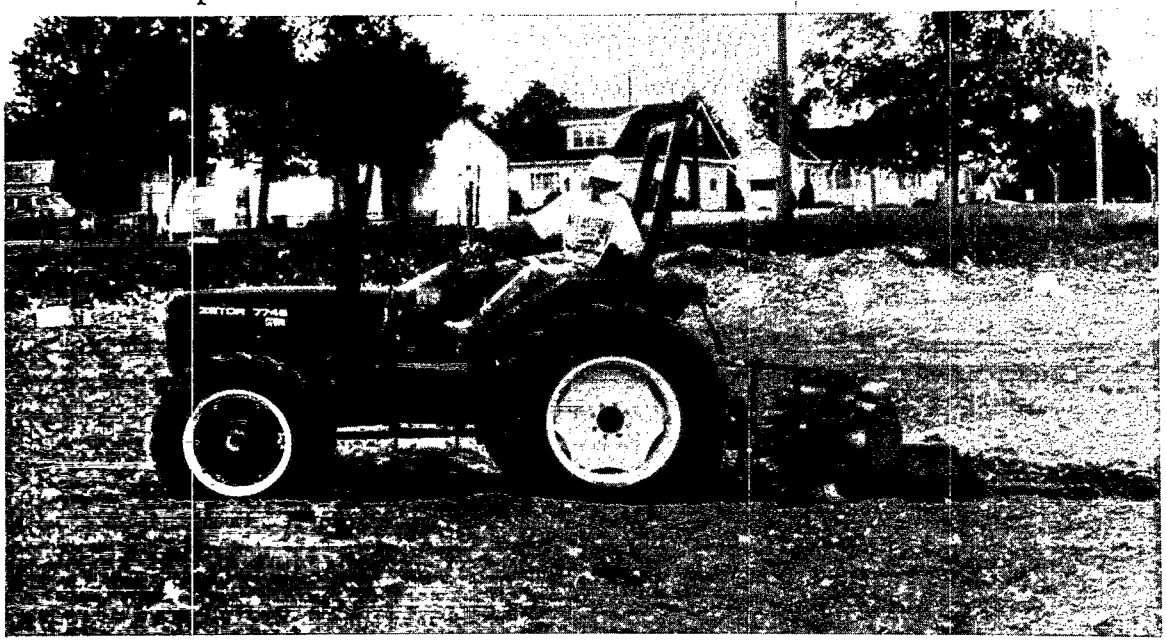
GRACE DEARBORN INC.
(DARAMEND™ Bioremediation Technology)

TECHNOLOGY DESCRIPTION:

GRACE Dearborn, Inc.'s organic amendment-enhanced bioremediation technology (DARAMEND™) is designed to degrade many organic contaminants, including pentachlorophenol (PCP), polynuclear aromatic hydrocarbons (PAH), and petroleum hydrocarbons in industrial soils and sediments. The technology treats batches of soil by incorporating DARAMEND™ soil amendments. These amendments are incorporated with conventional agricultural equipment, followed by regular tilling and irrigation. DARAMEND™ soil amendments are solid-phase products prepared from natural organic materials to have soil-specific particle size distribution, nutrient content, and nutrient release kinetics. Soil amendments sharply increase the ability of the soil matrix to supply water and nutrients to the microorganisms that degrade the hazardous compounds. The amendments can also transiently bind contaminants, reducing the acute toxicity of the soil aqueous phase. This reduction allows microorganisms to survive in soils containing very high concentrations of toxic compounds.

The technology has been applied to remediate soils both in situ and ex situ. In either case, soil may be treated in lifts up to two feet deep using available mixing equipment. DARAMEND™ treatment involves the following three fundamental steps:

- Preparation of the treatment area for the ex situ approach requires construction of a treatment cell that will contain any foreseeable free water. The in situ approach requires the treatment area to be cleared and ripped, to reduce soil compaction.
- Soil pretreatment includes removing debris larger than 10 inches, such as metal or rocks, that may damage the tilling equipment. Sediments undergoing treatment must be dewatered.
- The DARAMEND™ soil amendment is incorporated, usually at 1 percent to 5 percent by weight, followed by regular tilling and irrigating.



Daramend™ Bioremediation Technology

The SITE Program assesses but does not approve or endorse technologies.

Soil is tilled with a rotary tiller to reduce the variation in soil properties and contaminant concentrations. Tilling also incorporates the required soil amendments and helps deliver oxygen to contaminant-degrading microorganisms.

A spray irrigation system is used to maintain soil moisture in the desired range. If heavy precipitation results in the creation of leachate or surface run-off waters, they are collected and re-applied to the soil as needed.

Equipment needed to implement this technology is readily available; requirements include a rotary tiller, spray irrigation equipment, and excavation and screening equipment.

Depending on site-specific factors such as contaminant type and initial concentration, and project schedule and climate, a waterproof cover may be constructed over the treatment area.

WASTE APPLICABILITY:

The DARAMEND™ technology is applicable to soils and sediments with a wide range of organic contaminants. The technology has proven effective on soils with total PAH concentrations of up to 20,000 milligrams per kilogram (mg/kg), total petroleum hydrocarbon contamination up to 6,300 mg/kg, and PCP concentrations up to 680 mg/kg. Total PAHs have been consistently reduced to below 100 mg/kg with many individual PAHs reduced below 10 mg/kg. Chlorophenol species have been consistently reduced to below 5 mg/kg. This performance is often attained within a year; however, environmental and site-specific conditions may decrease or increase this treatment time.

Bench- and pilot-scale investigations have demonstrated the technology's applicability to PAH-contaminated sediment. The technology's ability to treat chlorinated pesticide contamination is under evaluation. Based on the technology's success, the principal target markets are wood treating, manufactured gas, and petroleum industries.

STATUS:

This technology was accepted into the SITE Demonstration Program in spring 1993. An evaluation of the ex situ performance of the DARAMEND™ technology began at the Domtar Wood Preserving facility in Trenton, Ontario, Canada during fall 1993 and was completed in summer 1994. Detailed results will be available in early 1995.

The demonstration is one component of a 5,000-ton remediation project underway at the industrial wood preserving site in Canada. Internal analyses of treated soil indicated significant reductions in the concentrations of both PAHs and chlorinated phenols.

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The SITE Program assesses but does not approve or endorse technologies.

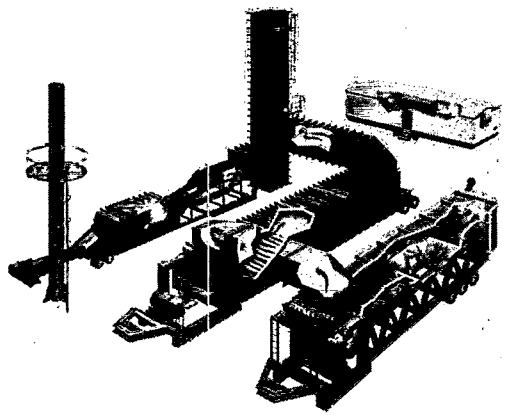
GRUPPO ITALIMPRESSE
(Developed by SHIRCO INFRARED SYSTEMS, INC.)
(Infrared Thermal Destruction)

TECHNOLOGY DESCRIPTION:

The infrared thermal destruction technology is a mobile thermal processing system that uses electrically-powered silicon carbide rods to heat organic wastes to combustion temperatures. Any remaining combustibles are incinerated in an afterburner. One configuration for this mobile system (see figure below) consists of four components: 1) an electric-powered infrared primary chamber; 2) a gas-fired secondary combustion chamber; 3) an emissions control system; and 4) a control center.

Waste is fed into the primary chamber and exposed to infrared radiant heat (up to 1,850 degrees Fahrenheit) provided by silicon carbide rods above the belt. A blower delivers air to selected locations along the belt to control the oxidation rate of the waste feed.

The ash material in the primary chamber is quenched by using scrubber water effluent. The ash is then conveyed to the ash hopper, where it is removed to a holding area and analyzed for organic contaminants, such as polychlorinated biphenyls (PCB).



Mobile Thermal Processing System

Volatile gases from the primary chamber flow into the secondary chamber, which uses higher temperatures, greater residence time, turbulence, and supplemental energy (if required) to destroy these gases. Gases from the secondary chamber are ducted through the emissions control system. In the emissions control system, the particulates are removed in a venturi scrubber. Acid vapor is neutralized in a packed tower scrubber. An induced draft blower draws the cleaned gases from the scrubber into the free-standing exhaust stack. The scrubber liquid effluent flows into a clarifier, where scrubber sludge settles out for disposal. The liquid then flows through an activated carbon filter for reuse or to a publicly owned treatment works for disposal.

WASTE APPLICABILITY:

This technology is suitable for soils or sediments with organic contaminants. Liquid organic wastes can be treated after mixing with sand or soil. Optimal waste characteristics are as follows:

- Particle size, 5 microns to 2 inches
- Moisture content, up to 50 percent by weight
- Density, 30 to 130 pounds per cubic foot
- Heating value, up to 10,000 British thermal units per pound
- Chlorine content, up to 5 percent by weight
- Sulfur content, up to 5 percent by weight
- Phosphorus, 0 to 300 parts per million (ppm)
- pH, 5 to 9
- Alkali metals, up to 1 percent by weight

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

EPA conducted two evaluations of the infrared system. A full-scale unit was evaluated during August 1987, at the Peak Oil Superfund site in Brandon, Florida. The system treated nearly 7,000 cubic yards of waste oil sludge containing PCBs and lead. A second pilot-scale demonstration took place at the Rose Township-Demode Road Superfund site in Michigan, during November 1987. Organics, PCBs, and metals in soil were the target waste compounds to be immobilized. In addition, the technology has been used to remediate PCB contamination at the Florida Steel Corporation and the LaSalle Electric Superfund sites. Two Applications Analysis Reports (EPA/540/A5-89/010 and EPA/A5-89/007) and two Technology Evaluation Reports (EPA/540/5-88/002a and EPA/540/5-89/007a) are available from EPA.

DEMONSTRATION RESULTS:

The results from the two SITE demonstrations are summarized below.

- PCBs were reduced to less than 1 ppm in the ash, with a destruction removal efficiency (DRE) for air emissions greater than 99.99 percent (based on detection limits).
- In the pilot-scale demonstration, the Resource Conservation and Recovery Act (RCRA) standard for particulate emissions (180 milligrams per dry standard cubic meter) was achieved. In the full-scale demonstration, however, this standard was not met in all runs because of scrubber inefficiencies.
- Lead was not immobilized; however, it remained in the ash, and significant amounts were not transferred to the scrubber water or emitted to the atmosphere.
- The pilot test demonstrated satisfactory performance with high feed rate and reduced power consumption when fuel oil was added to the waste feed and the primary chamber temperature was reduced.

Results from the two demonstrations, plus eight other case studies, indicate the following:

- The process is capable of meeting both RCRA and Toxic Substance Control Act (TSCA) DRE requirements for air emissions and particulate emissions. Restrictions in chloride levels in the feed waste may be necessary. PCB remediation has consistently met the TSCA guidance level of 2 ppm in ash.
- Economic analysis suggests an overall waste remediation cost up to $800 per ton.

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Note: This technology is no longer available through vendors in the United States.

The SITE Program assesses but does not approve or endorse technologies.

HIGH VOLTAGE ENVIRONMENTAL APPLICATIONS, INC.
(formerly ELECTRON BEAM RESEARCH FACILITY, FLORIDA INTERNATIONAL UNIVERSITY, AND UNIVERSITY OF MIAMI)
(High-Energy Electron Irradiation)

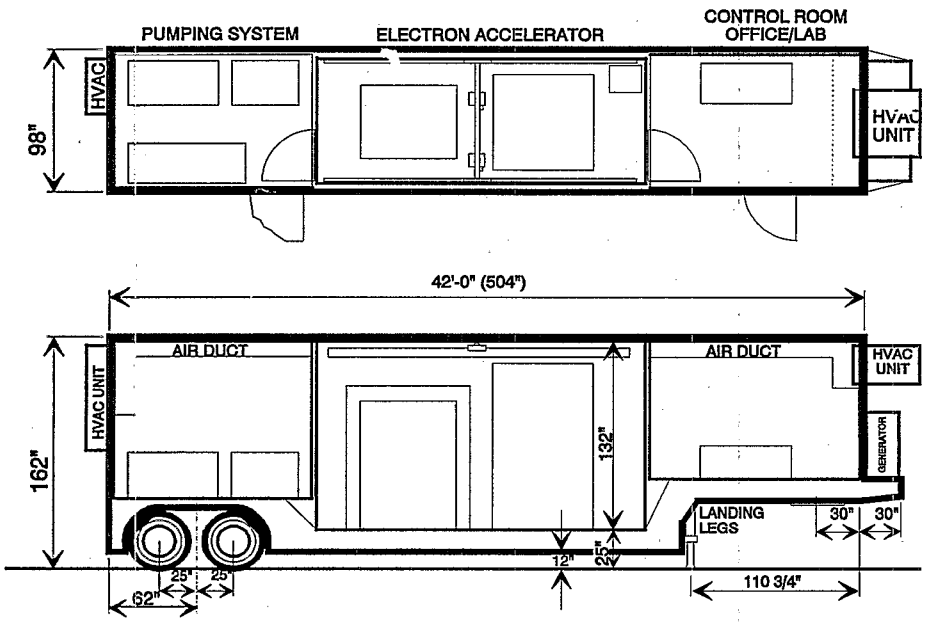
TECHNOLOGY DESCRIPTION:

High-energy electron irradiation of water solutions and sludges produces a large number of very reactive chemical species, including the aqueous electron (e^-_{aq}), the hydrogen radical (H·), and the hydroxyl radical (OH·). These short-lived intermediates react with organic contaminants, transforming them to nontoxic byproducts.

In the principal reaction, the e^-_{aq} ion transfers to halogen-containing compounds, breaking the halogen-carbon bond and liberating halogen anions such as chlorine (Cl^-) or bromine (Br^-). The hydroxyl radical can undergo addition or hydrogen abstraction reactions, producing organic free radicals that decompose in the presence of other hydroxyl radicals and water. In most cases, organics are converted to carbon dioxide, water, and salts. Lower molecular weight aldehydes and carboxylic acids form at low concentrations in some cases. These compounds are biodegradable end products.

During the high-energy electron irradiation process, electricity generates high voltage electrons. The electrons are accelerated by the voltage to approximately 95 percent of the speed of light. They are then directed into a thin stream of water or sludge. All reactions are complete in less than 0.1 second. The electron beam and waste flow are adjusted to deliver the necessary dose of electrons. Although this is a form of ionizing radiation, there is no residual radioactivity.

A full-scale facility in Miami, Florida, can treat more than 170,000 gallons per day. This facility is equipped to handle tank trucks carrying up to 6,000 gallons of waste. High Voltage Environmental Applications, Inc., developed a mo-



The Mobile Electron Beam Hazardous Waste Treatment System

The SITE Program assesses but does not approve or endorse technologies.

bile facility to demonstrate the treatment process (see figure previous page).

WASTE APPLICABILITY:

This treatment process can effectively treat more than 50 common organic compounds. These compounds include the following:

- trihalomethanes (such as chloroform), which are found in chlorinated drinking water;
- chlorinated solvents, including carbon tetrachloride, trichloroethane, tetrachloroethene (PCE), trichloroethene (TCE), ethylene dibromide, dibromochloropropane, hexachlorobutadiene, and hexachloroethane;
- aromatics found in gasoline, including benzene, toluene, ethylbenzene, and xylene;
- chlorobenzene and dichlorobenzenes;
- phenol;
- dieldrin, a persistent pesticide;
- polychlorinated biphenyls; and
- a variety of other organic compounds.

The treatment process is appropriate for removing various hazardous organic compounds from aqueous waste streams and sludges containing up to 8 percent solids.

STATUS:

The high-energy electron irradiation process was accepted into the SITE Emerging Technology Program in June 1990. Based on results from the Emerging Technology Program, the process was invited to participate in the Demonstration Program. The treatment process was demonstrated at the U.S. Department of Energy's Savannah River site in Aiken, South Carolina during September 1994. The demonstration took place on a portion of the Savannah River site known as M-Area. Chlorinated solvents from fuel and target manufacturing operations were discharged to an unlined basin at M-Area for almost 20 years. Detailed results from the demonstration will be available in 1995.

Under the Emerging Technology Program, detailed studies were completed for eight organic compounds: TCE, PCE, chloroform, carbon tetrachloride, methylene chloride, benzene, toluene, and phenol. Removal efficiencies were determined at three solute concentrations and three pHs (representing varying carbonate/bicarbonate concentrations), and in the presence and absence of 3 percent clay. Reaction by-products were determined for all six compounds. For the most part, the eight compounds were mineralized. Trace quantities of formaldehyde and other low molecular weight aldehydes were detected. Formic acid was also detected at low concentrations; however, the eight compounds were not toxic at these concentrations. Papers are pending that summarize the study results.

Additional studies are underway to determine destruction efficiencies with a higher concentration of solids and characterize carbon tetrachloride and methylene chloride by-products.

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The SITE Program assesses but does not approve or endorse technologies.

HORSEHEAD RESOURCE DEVELOPMENT CO., INC.
(Flame Reactor)

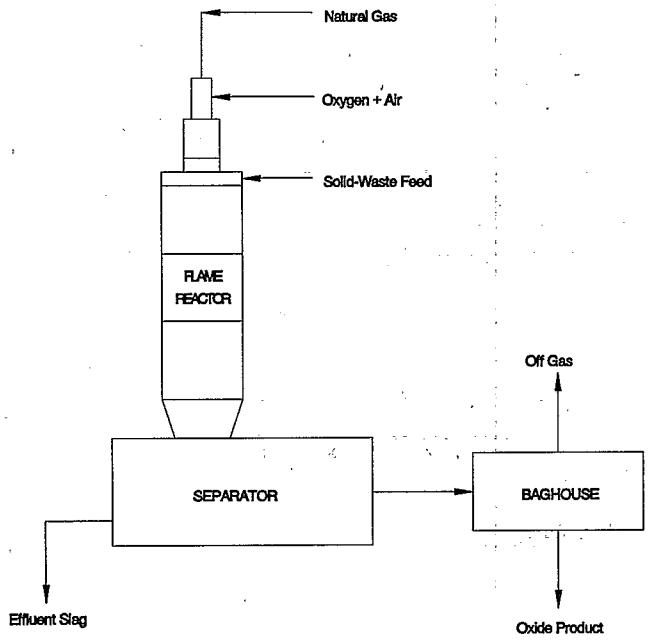
TECHNOLOGY DESCRIPTION:

The Horsehead Resource Development Co., Inc. (HRD), flame reactor system is a patented, hydrocarbon-fueled, flash-smelting system that treats residues and wastes contaminated with metals (see figure below). The reactor processes wastes with hot (greater than 2,000 degrees Celsius) reducing gases produced by combusting solid or gaseous hydrocarbon fuels in oxygen-enriched air. In a compact, low-capital cost reactor, the feed materials react rapidly, allowing a high waste throughput. The end products are a non-leachable, glass-like slag; a potentially recyclable, heavy metal-enriched oxide; and in some cases, a metal alloy. Volume reduction (of waste to slag plus oxide) depends on the chemical and physical properties of the waste. The volatile metals are fumed and captured in a product dust collection system; nonvolatile metals partition to the slag or may be separated as a molten alloy. Organic compounds are destroyed at the elevated temperature of the flame reactor technology.

In general, the system requires that wastes be dry enough (less than 5 percent total moisture) to be pneumatically-fed, and fine enough (less than 200 mesh) to react rapidly. Larger particles (up to 20 mesh) can be processed; however, the efficiency of metals recovery is decreased. The test facility has a capacity of up to 3 tons per hour. Individual units can be scaled to a capacity of 7 tons per hour.

WASTE APPLICABILITY:

The flame reactor system can be applied to granular solids, soil, flue dusts, slags, and sludges that contain heavy metals. The flame reactor technology has successfully treated the following wastes: 1) electric arc furnace dust, 2) lead blast furnace slag, 3) soil, 4) iron residues, 5) primary copper flue dust, 6) lead smelter nickel matte, 7) zinc plant leach residues and purification residues, 8) brass mill dusts and fumes, and 9) electroplating sludges.



HRD Flame Reactor Process Flow

The SITE Program assesses but does not approve or endorse technologies.

The system has successfully treated the following metal-bearing wastes: zinc (up to 40 percent); lead (up to 10 percent); chromium (up to 4 percent); cadmium (up to 3 percent); arsenic (up to 1 percent); copper (up to 8 percent); cobalt; and nickel. The system can also treat soils that are contaminated with metals, with or without a variety of toxic organics.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1990. Currently, the prototype flame reactor technology system operates with a capacity of 1 to 3 tons per hour in a stationary mode at HRD's facility in Monaca, Pennsylvania. EPA and HRD believe that a mobile version of the system could be designed and constructed for on-site treatment at hazardous waste sites.

The SITE demonstration was conducted from March 18 to 23, 1991, on secondary lead smelter-soda slag from the National Smelting and Refining Company (NSR) Superfund site in Atlanta, Georgia. The test was conducted at the Monaca, Pennsylvania facility under a Resource Conservation and Recovery Act research, development, and demonstration permit. This permit allows treatment of wastes containing high concentrations of metals, but only negligible concentrations of organics.

The major objectives of the SITE technology demonstration were to investigate the reuse potential of the recovered metal oxides, evaluate the levels of contaminants in the residual slag and their leaching potential, and determine the efficiency and economics of processing.

A 30,000-standard-tons-per-year commercial flame reactor plant processes steel mill baghouse dust (K061) exclusively at the North Star Steel Mini Mill near Beaumont, Texas. The plant was activated June 1, 1993, and is capable of performing as designed.

DEMONSTRATION RESULTS:

Approximately 72 tons of NSR waste material were processed during the demonstration. Partial test results are shown in the table below.

Metal Concentration Ranges in Influent and Effluent

	Waste Feed (mg/kg)*	Effluent Slag (mg/kg)	Oxide Product (mg/kg)
Arsenic	428-1040	92.1-1340	1,010-1,170
Cadmium	356-512	<2.3-13.5	1,080-1,380
Copper	1,460-2,590	2,730-3,890	1,380-1,780
Iron	95,600-130,000	167,000-228,000	29,100-35,600
Lead	48,200-61,700	1,560-11,400	159,000-184,000
Zinc	3,210-6,810	711-1,680	10,000-16,200

* milligrams per kilogram

All effluent slag passed toxicity characteristic leaching procedure criteria. Study of the reuse potential of the oxide product is ongoing. The Technology Evaluation Report (EPA/540/5-91/005) and the Applications Analysis Report (EPA/540/A5-91/005) are available from EPA.

FOR FURTHER INFORMATION:

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The SITE Program assesses but does not approve or endorse technologies.

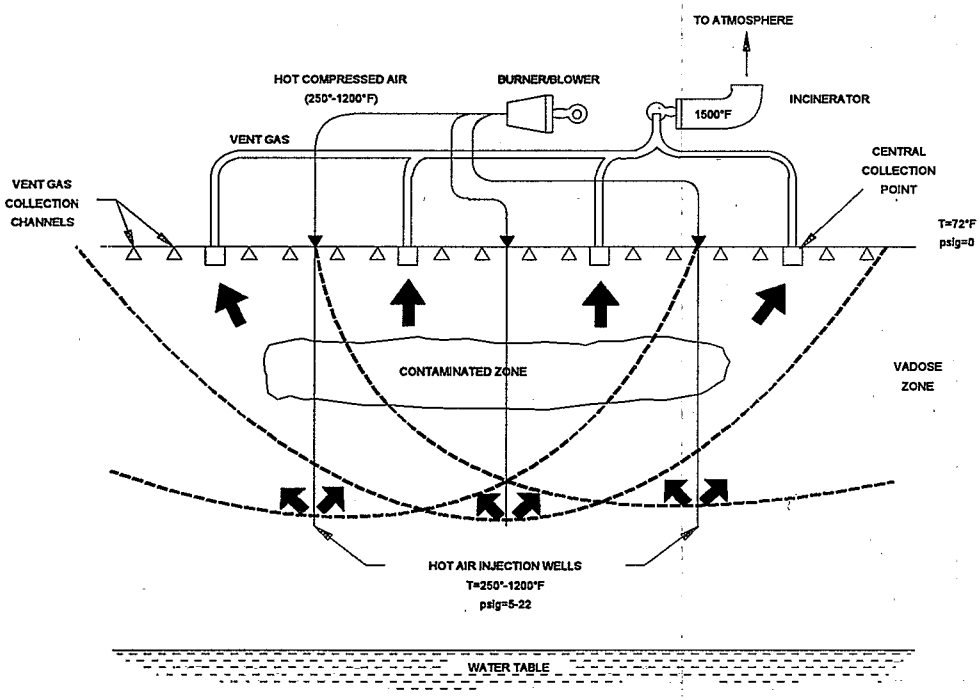
HRUBETZ ENVIRONMENTAL SERVICES, INC.
(HRUBOUT® Process)

TECHNOLOGY DESCRIPTION:

The HRUBOUT® process is a thermal, in situ and ex situ treatment process designed to remove volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC) from contaminated soils. As part of the in situ process, heated air is injected into the soil below the contamination zone, evaporating soil moisture and removing volatile and semivolatile hydrocarbons. As the water evaporates, soil porosity and permeability increase, further facilitating the air flow at higher temperatures. As the soil temperature increases further, the less volatile constituents volatilize or are thermally oxidized.

Injection wells are drilled in a predetermined distribution pattern to depths below the contamination. The wells are equipped with steel casing, perforated at the bottom, and cemented into the hole above the perforations. Heated, compressed air is introduced at temperatures up to 1,200 degrees Fahrenheit (°F), and the pressure is slowly increased. As the air progresses upward through the soil, the moisture is evaporated, taking with it the VOCs and SVOCs. A surface collection system captures the exhaust gases under negative pressure. These gases are transferred to a thermal oxidizer, where the hydrocarbons are thermally destroyed at 1,500 °F.

The air is heated in an adiabatic burner at 2.9 million British thermal units (MMBtu) per hour. The incinerator has a rating of 3.1 MMBtu/hour. The air blower can deliver up to 8,500 pounds per hour. The units employ a fully-modulating fuel train that is fueled by natural gas or propane. All equipment is mounted on custom-designed mobile units and operates 24 hours per day.



HRUBOUT® Process

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The HRUBOUT® process can remediate soils contaminated with halogenated or non-halogenated organic volatiles and semi-volatiles, such as gasoline, diesel oil, jet fuel, heating oil, chemical solvents or other hydrocarbon compounds. There is no residual output from the treatment site, eliminating any future liability.

STATUS:

The HRUBOUT® process was accepted into the SITE Demonstration Program in July 1992. The technology was demonstrated at Kelly Air Force Base in San Antonio, Texas, from January through February 1993. Preliminary demonstration results were published in a demonstration bulletin (EPA/540/MR-93/524). This document is available from EPA.

In 1988, approximately 80,000 gallons of JP-4 jet fuel spilled from a ruptured, high-pressure fuel pipeline on Kelly Air Force Base. A 30-by-40-foot area of the spill site was chosen as the treatment area. Six heated air injection wells, spaced on a 3-by-2 grid 10 feet apart, were drilled to a depth of approximately 20 feet.

In September 1993, an in situ project was completed at the Canadian Forces military base in Ottawa, Ontario, Canada. Levels up to 1900 parts per million (ppm) of total petroleum hydrocarbons (TPH) were encountered over an area about 17-by-17-feet on the base. Five injection wells were drilled to a depth of 30 feet. After 12 days of treatment, borehole samples ranged from non-detect to 215 ppm TPH, successfully meeting closure requirements of 450 ppm TPH minimum.

The new containerized version of the HRUBOUT® process was tested in July 1993 at a West Texas site contaminated with Varsol, or naphtha. The soil was excavated so it could be treated in Hrubetz's insulated container. The soil tested 1550 ppm of TPH before treatment. Three loads were treated for about 60-65 hours each. Post-treatment samples tested from non-detect to 7 ppm of TPH, meeting the Texas Water Commission's background target level of 37 ppm. Large-scale mobile container units, holding up to 40 cubic yards, and capable of treating a load in 8 hours, are now being developed for ex situ application.

Additional tests conducted by Hrubetz have shown that excavated contaminated soils may be treated by distributing the soils over a horizontal, perforated piping grid. The process injects the pressurized, heated air via the grid system, collects the resultant vapors beneath an impermeable covering, and directs those vapors into the thermal oxidizer.

Three patents have been granted, and additional patents are pending. The process was approved by the Texas Natural Resources Conservation Commission in 1991.

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The SITE Program assesses but does not approve or endorse technologies.

HUGHES ENVIRONMENTAL SYSTEMS, INC.
(Steam Enhanced Recovery Process)

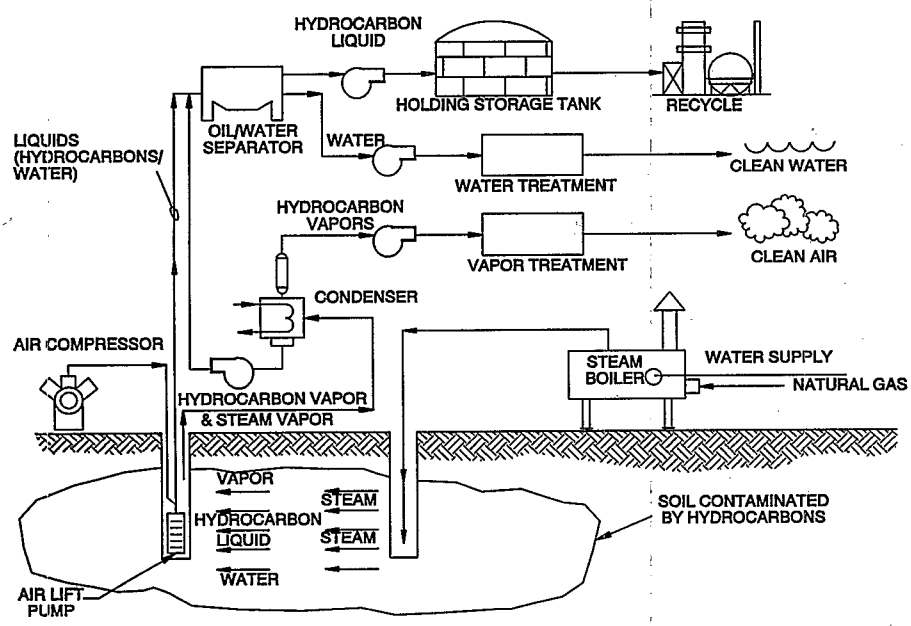
TECHNOLOGY DESCRIPTION:

The Steam Enhanced Recovery Process (SERP) removes most volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) from contaminated soils in situ both above and below the water table (see figure below). The technology is applicable to the in situ remediation of contaminated soils below ground surface and below or around permanent structures. The process accelerates contaminant removal rates and can be effective in all soil types.

Steam is forced through the soil by injection wells to thermally enhance the recovery process. Extraction wells are used for two purposes: to pump and treat groundwater, and to transport steam and vaporized contaminants to the surface. Recovered nonaqueous liquids are separated by gravity separation. Hydrocarbons are collected for recycling, and water is treated before being discharged to a storm drain or sewer. Vapors can be condensed and treated by any of several vapor treatment techniques (for example, thermal oxidation and catalytic oxidation). The technology uses readily available components such as extraction and monitoring wells, manifold piping, vapor and liquid separators, vacuum pumps, and gas emission control equipment.

WASTE APPLICABILITY:

The process can extract VOCs and SVOCs from contaminated soils and perched groundwater. Compounds suitable for treatment are hydrocarbons such as gasoline and diesel and jet fuel; solvents such as trichloroethene, trichloroethane, and dichlorobenzene; or a mixture of these compounds. After application of the process, subsurface conditions are excellent for biodegradation of residual contaminants. The process cannot be applied to contaminated soil very near the ground surface unless a cap exists. Denser-



Steam Enhanced Recovery Process

The SITE Program assesses but does not approve or endorse technologies.

than-water compounds can be treated only in low concentrations unless a geologic barrier exists to prevent downward percolation.

STATUS:

The SITE demonstration of this technology began in August 1991 and was completed in September 1993. Soil at the site in Huntington Beach, California was contaminated by a large diesel fuel spill. The Demonstration Bulletin (EPA/540/HR-94/510) is available from EPA. The Innovative Technology Evaluation Report will be available from EPA in late 1994.

For more information regarding this technology, see the Berkeley Environmental Restoration Center (Completed Projects), or Praxis Environmental Technologies, Inc., (Ongoing Projects) profiles in the Demonstration Program section. This technology is no longer available through this vendor. Contact the EPA Project Manager for further information.

DEMONSTRATION RESULTS:

Preliminary evaluation of the posttreatment data suggests the following conclusions:

- The geostatistical weighted average soil total petroleum hydrocarbons (TPH) concentration in the treatment area was 2,290 milligrams per kilogram (mg/kg). The 90 percent confidence interval for this average concentration is 996 mg/kg to 3,570 mg/kg, which shows that there is a high probability that the technology did not meet the cleanup criterion. Seven percent of soil samples had TPH concentrations in excess of 10,000 mg/kg.
- The geostatistical weighted average soil total recoverable petroleum hydrocarbons (TRPH) concentration was 1,680 mg/kg with a 90 percent confidence interval of 676 mg/kg to 2,680 mg/kg. Levels of benzene, toluene, ethylbenzene, and xylenes (BTEX) were below the detection limit (6 micrograms per kilogram) in post-treatment soil samples; BTEX was detected at low mg/kg levels in a few pretreatment soil samples.
- Analysis of triplicate samples showed marked variability in soil contaminant concentration over short distances. Analogous results for TPH and TRPH triplicate samples suggest that the contaminant concentration variability exists within the site soil matrix and is not the result of analytical techniques. This variability is the reason that confidence intervals for the average concentrations are so large.
- The data suggests that lateral or downward migration of contaminants did not occur during treatment.

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The SITE Program assesses but does not approve or endorse technologies.

IIT RESEARCH INSTITUTE/ BROWN AND ROOT ENVIRONMENTAL
(Radio Frequency Heating)

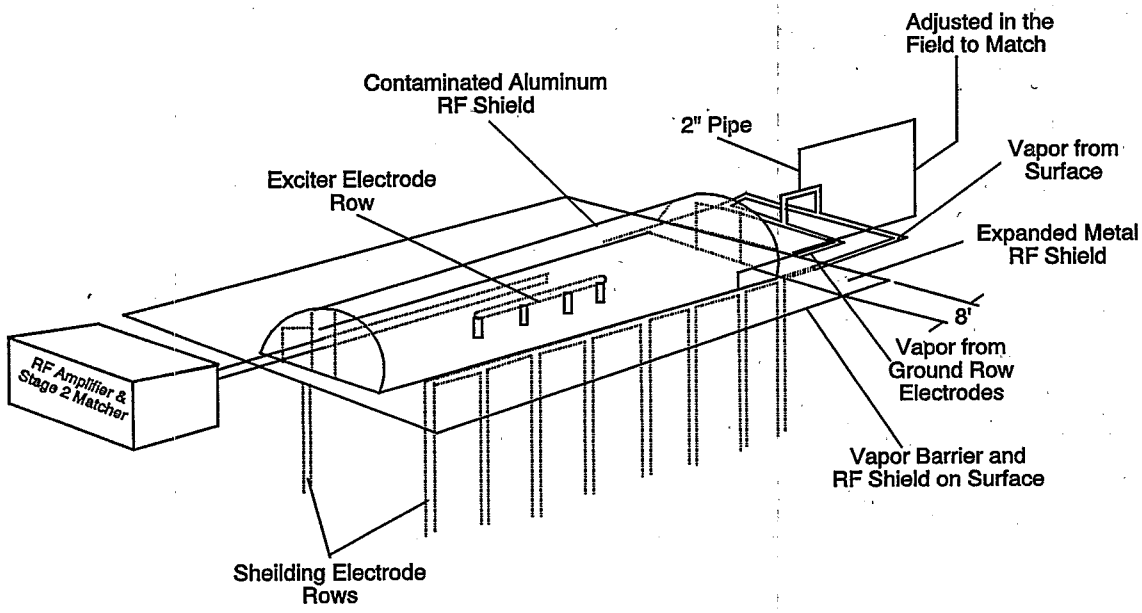
TECHNOLOGY DESCRIPTION:

Radio frequency heating (RFH) is an in situ process that uses electromagnetic energy to heat soil and enhance soil vapor extraction (SVE). Developed by IIT Research Institute (IITRI), the patented RFH technique heats a discrete volume of soil using rows of vertical electrodes embedded in the soil (or media). Heated soil volumes are bounded by two rows of ground electrodes with energy applied to a third row midway between the ground rows. The three rows act as a buried triplate capacitor. When energy is applied to the electrode array, heating begins in the top center and proceeds vertically downward and laterally outward through the soil volume. The technique has heated soil to well over 300 degrees Celsius.

RFH enhances SVE for two reasons: 1) contaminant vapor pressures are increased by heating, and 2) the soil permeability is increased by drying. Extracted vapor can then be treated by a variety of existing technologies, such as granular activated carbon or incineration.

WASTE APPLICABILITY:

RFH enhances SVE to remove petroleum hydrocarbons, volatile organic compounds (VOC), semivolatile organic compounds (SVOC), and pesticides from soils. The technology is most



Radio Frequency In Situ Heating System

The SITE Program assesses but does not approve or endorse technologies.

efficient in subsurface areas with low groundwater recharge. In theory, the technology should be applicable to any polar compound in any non-metallic media.

STATUS:

The RFH technique was accepted into the SITE Demonstration Program in summer 1992. The technique was demonstrated in summer 1993 at Kelly Air Force Base (AFB), Texas, as part of a joint project with the U.S. Air Force. Brown and Root Environmental was the prime contractor for the evaluation and implementation of RFH for the U.S. Air Force. This technique and an alternative RFH technology developed by KAI were demonstrated and compared in June 1994 at Kelly AFB. Final technical reports will be available from Armstrong Laboratory and EPA in early 1995. The reports will contain engineering evaluation of this technique and the KAI technology. For further information on the KAI technology, see the profile in the Demonstration Program Completed Project section.

One additional field test of this technology will occur within the next year. The test will be conducted at Sandia National Laboratory (SNL) in Albuquerque, New Mexico. The SNL site is a former chemical waste landfill where silty sand is contaminated with VOCs and SVOCs.

Two previous field tests were completed using in situ RFH. The technology was tested at a fire training pit, located at the Volk Air National Guard Base in Camp Douglas, Wisconsin. The sandy soil in the pit was contaminated with jet fuel. The second test was completed at Rocky Mountain Arsenal in Colorado, where clayey soil was contaminated by organochlorine-pesticides.

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The SITE Program assesses but does not approve or endorse technologies.

KAI TECHNOLOGIES, INC./ BROWN AND ROOT ENVIRONMENTAL
(Radio Frequency Heating)

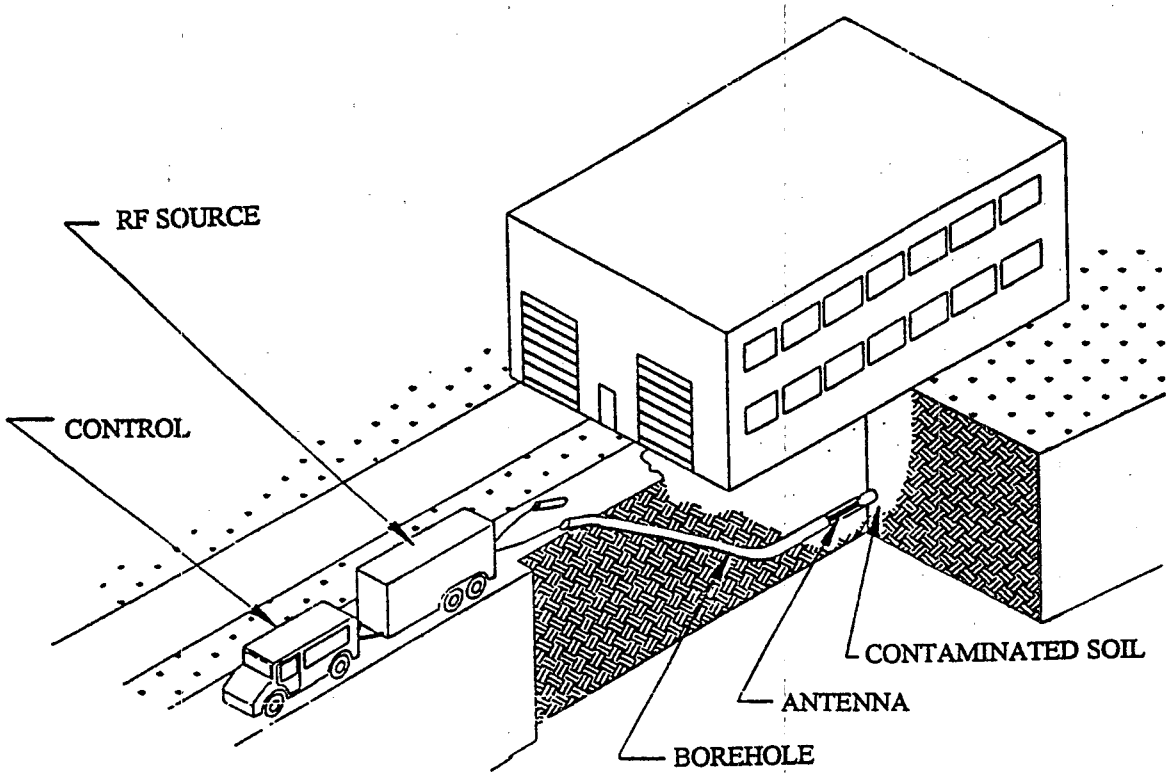
TECHNOLOGY DESCRIPTION:

Radio frequency heating (RFH) is an in situ process that uses electromagnetic energy to heat soil and enhance soil vapor extraction (SVE). The patented RFH technique, developed by KAI Technologies, Inc., uses an antenna-like applicator inserted in a single borehole to heat a volume of soil. Large volumes can be treated with arrays of antennas that are selected and sequentially positioned within their respective boreholes by the RFH control system. When energy is applied to the antenna, heating begins near the borehole and proceeds outward. The technique has heated soil to well over 250 degrees Celsius.

RFH enhances SVE for two reasons: 1) contaminant vapor pressures are increased by heating; and 2) the soil permeability is increased by drying. Extracted vapor can then be treated by a variety of existing technologies.

WASTE APPLICABILITY:

The RFH technique has been tested on pilot-scale vertical and horizontal antenna orientations to remove petroleum hydrocarbons and volatile and semivolatile organics from soils. The technology is most efficient in subsurface areas with low groundwater recharge. In theory, the technology should be applicable to any polar compound in any non-metallic media. The



KAI Antenna System

The SITE Program assesses but does not approve or endorse technologies.

flexible design permits easy access for in situ treatment of organics and pesticides under buildings or fuel storage tanks.

STATUS:

The KAI RFH technique was accepted into the SITE Demonstration Program in summer 1992. The technique was demonstrated between January and March 1994 at Kelly Air Force Base, Texas, as part of a joint project with the U.S. Air Force Armstrong Laboratory. Brown and Root Environmental was the prime contractor for the evaluation and implementation of RFH for the U.S. Air Force. An earlier field demonstration of the IIT Research Institute RFH technology was completed in summer 1993 at the same site for comparison. Final technical reports will be available from Armstrong Laboratory and EPA in early 1995. The reports will contain engineering evaluations of both techniques.

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The SITE Program assesses but does not approve or endorse technologies.

MAGNUM WATER TECHNOLOGY
(CAV-OX® Process)

TECHNOLOGY DESCRIPTION:

The CAV-OX® process uses a synergistic combination of hydrodynamic cavitation and ultraviolet (UV) radiation to oxidize contaminants in water. The process is designed to remove organic contaminants from wastewater and groundwater without releasing volatile organic compounds into the atmosphere. Contaminants in aqueous waste streams often meet discharge limits at optimal conditions when treated with the process. The CAV-OX® process cannot handle free product or highly turbid waste streams, since these conditions tend to lower the UV reactors' efficiencies. However, the CAV-OX® cavitation chamber's efficiency is unaffected in such cases.

Free radicals are generated and maintained by the system's combination of hydrodynamic cavitation, UV excitation, and, where necessary, addition of hydrogen peroxide and metal catalysts. Neither the cavitation chamber nor the UV lamp or hydrogen peroxide reaction generates toxic by-products or air emissions. UV lamp output can be varied from 360 watts to over 20,000 watts, depending on the waste stream.

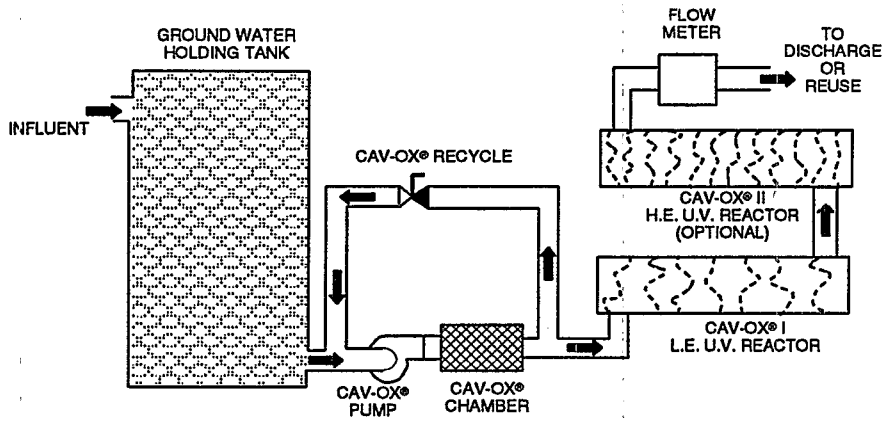
Magnum Water Technology estimates the cost of using the CAV-OX® process to be about half the cost of other advanced UV oxidation systems, and substantially less expensive than carbon adsorption. In addition, because the process equipment has only one moving part, maintenance costs are minimal. The CAV-OX® process does not exhibit the quartz tube scaling common with other UV equipment. Langelier's Index of Scaling is shifted negative by the CAV-OX® process.

WASTE APPLICABILITY:

The process is designed to treat liquid waste, specifically groundwater or wastewater contaminated with organic compounds. Contaminants such as halogenated solvents; phenol; pentachlorophenol; pesticides; polychlorinated biphenyls; explosives; benzene, toluene, ethylbenzene, and xylenes; methyl tertiary butyl ether; cyanide; and other organic compounds are suitable for this treatment process. Organics such as benzene can be treated to nondetectable levels; others, such as 1,1-dichloroethane, are typically reduced by 96 percent. Organisms such as *Salmonella* and *E. Coli* are also significantly reduced.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1992, and was demonstrated for four weeks in March 1993 at Edwards Air Force Base Site 16 in California. The Demonstration Bulletin



The CAV-OX® Process

The SITE Program assesses but does not approve or endorse technologies.

(EPA/540/MR-93/524) is available from EPA. The Applications Analysis Report (EPA/540/AR-93/520) was published in May 1994.

The CAV-OX® process has been tested at several private and public sites, including the San Bernardino and Orange County Water Departments in California. Tests at a Superfund site treated leachate containing 15 different contaminants. Pentachlorophenol, one of the major contaminants, was reduced by 96 percent in one test series. In other tests, the process successfully treated cyanide contamination. The process has remediated a former gasoline station site over a 2-year period. A second gasoline station site is currently being remediated using this process.

Tests in Mexico on difficult pharmaceutical contaminants from a plant process stream were successful. The high chemical oxygen demand (approximately 120,000 parts per million) was reduced 86 percent. Tests at a California chemical plant reduced process stream contaminants by 80 percent.

DEMONSTRATION RESULTS:

The CAV-OX® process achieved removal efficiencies of greater than 99.9 percent for trichloroethene, benzene, toluene, ethylbenzene, and xylenes. No quartz tubes scaling was observed. Preliminary demonstration results for the CAV-OX® process are shown in the table below.

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H_2O_2[1] Concentrations (mg/L)[2]	CAV-OX® I Flow (gpm)[3]	CAV-OX® I Removal Efficiencies (%) TCE	Benzene	Toluene	Xylene	CAV-OX® II Flow (gpm)	Removal Efficiencies (%) TCE 5-kW[4]	TCE 10-kW	Benzene 5-kW	Benzene 10-kW	Toluene 5-kW	Toluene 10-kW	Xylene 5-kW	Xylene 10-kW
33.1	0.5	99.9	>99.9	99.4	92.9	1.5	99.6	99.2	99.4	98.8	>99.9	98.6	>99.9	>99.9
23.4	0.6	99.9	>99.9	>99.9	>99.9	2.0	99.7	99.7	99.5	99.6	>99.9	>99.9	>99.9	>99.9
4.9	1.5	71.4	88.6	87.4	65.6	4.0	87.7	98.1	89.7	98.7	88.8	97.1	78.7	87.2
48.3	0.6	99.7	>99.9	>99.9	>99.9	1.4	99.8	99.7	99.8	99.8	>99.9	>99.9	98.7	>99.9
6.0	0.7	87.8	96.9	94.5	92.1	1.9	98.4	99.3	98.8	99.3	96.9	98.6	93.6	97.0
4.9	1.5	61.7	81.6	83.8	80.2	3.9	85.1	97.1	89.5	97.8	91.8	97.9	90.4	96.0
5.9	0.5	96.4	99.4	99.8	98.9	1.4	99.6	99.4	99.6	99.6	99.8	99.8	99.5	99.5
5.9	0.7	87.1	96.5	97.6	98.1	1.9	97.8	99.2	99.4	99.5	99.5	99.7	99.2	99.7
6.1	1.5	60.6	86.1	87.3	>99.9	4.0	86.3	98.9	93.5	99.5	94.5	99.6	95.4	>99.9
0	-	-	-	-	-	1.6	94.1	99.2	49.1	68.1	20.7	54.7	43.3	46.7
0	-	-	-	-	-	1.8	80.6	97.6	38.5	60.5	48.6	75.2	56.9	83.8

[1] hydrogen peroxide [2] milligrams per liter [3] gallons per minute [4] kilowatts

Preliminary CAV-OX® Process Demonstration Results

The SITE Program assesses but does not approve or endorse technologies.

MAXYMILLIAN TECHNOLOGIES, INC. (formerly CLEAN BERKSHIRES INC.)
(Mobile Thermal Desorption System)

TECHNOLOGY DESCRIPTION:

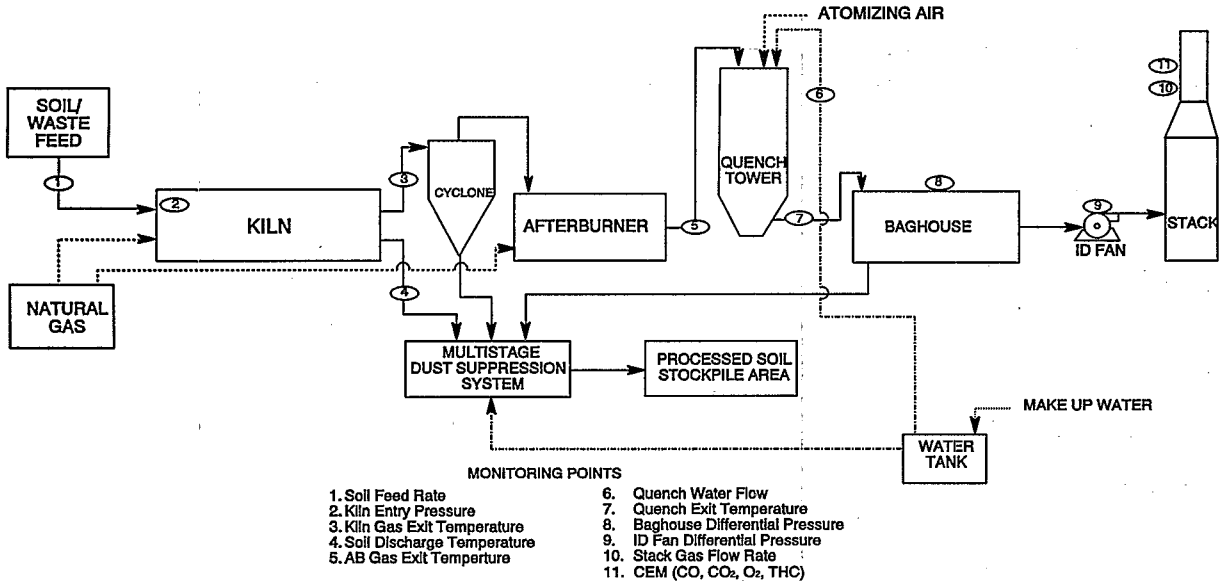
Maxymillian Technologies, Inc.'s, Mobile Thermal Desorption System (TDS) uses rotary kiln technology to remove contaminants from soils. The TDS can remediate soils contaminated with volatile organic compounds (VOC), semivolatile organic compounds (SVOC), and polynuclear aromatic hydrocarbons (PAH). The TDS is fully transportable, requires a footprint of 100-by-140 feet, and can be set up on site in 4 to 6 weeks. The system combines high throughput with the ability to remediate mixed consistency soil, including sands, silts, clays, and tars.

The TDS consists of the following components (see figure below):

- Waste feed system
- Rotary kiln drum desorber
- Cyclone
- Afterburner
- Quench tower
- Baghouse
- Fan and exhaust stack
- Multistage dust suppression system
- Process control room

Soil is first shredded, crushed, and screened to achieve a uniform particle size of less than 0.75 inch. Feed soils are also mixed to achieve uniform moisture content and heating value.

The thermal treatment process involves two steps: contaminant volatilization followed by gas treatment. During the volatilization step, contaminated materials are exposed to temperatures ranging from 600 to 1,000 degrees Fahrenheit (°F) in a co-current flow rotary kiln drum desorber; contaminants volatilize to the gas phase. Clean soils are then discharged through a multi-stage dust suppression system for remoisturization, and are then stockpiled for testing.



Mobile Thermal Desorption System

The SITE Program assesses but does not approve or endorse technologies.

The gas and particulate stream passes from the kiln to the cyclone, where coarse particles are removed. The stream then enters the afterburner, which destroys airborne contaminants at temperatures ranging from 1,600 to 2,000 °F. The gas stream is cooled by quenching before passing through a high-efficiency bag-house, where fine particles are removed. The clean gas is then released to the atmosphere through a 60-foot stack. Processed soil, after discharge from the dust suppression system, is stockpiled and allowed to cool prior to sampling.

WASTE APPLICABILITY:

The TDS is designed to remove a wide variety of contaminants from soil, including VOCs, SVOCs, PAHs, coal tars, and cyanide.

STATUS:

The TDS was accepted into the SITE Demonstration Program in 1993. The demonstration was conducted in November and December 1993 at the Niagara Mohawk Power Corporation's Harbor Point site, a former gas plant in Utica, New York. During the demonstration, the TDS processed three replicate runs of four separate waste streams while measuring stack emissions and processed soil for cleanup levels.

The TDS effectively remediated coal tar soils, purifier wastes, harbor sediments, and water gas plant soils while maintaining acceptable emissions. The TDS removed VOCs, PAHs, and cyanide from contaminated soils to below detection limits and achieved destruction and removal efficiencies greater than 99.99 percent. Detailed results from the demonstration will be published in late 1994.

Since the demonstration, the TDS was reconfigured and transported back to North Adams, Massachusetts, where it operates as Re·Soil, a soil recycler for petroleum contaminated soils. The TDS is available for commercial-scale soil remediation throughout the country.

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The SITE Program assesses but does not approve or endorse technologies.

NORTH AMERICAN TECHNOLOGIES GROUP, INC.
(Oleophilic Amine-Coated Ceramic Chip)

TECHNOLOGY DESCRIPTION:

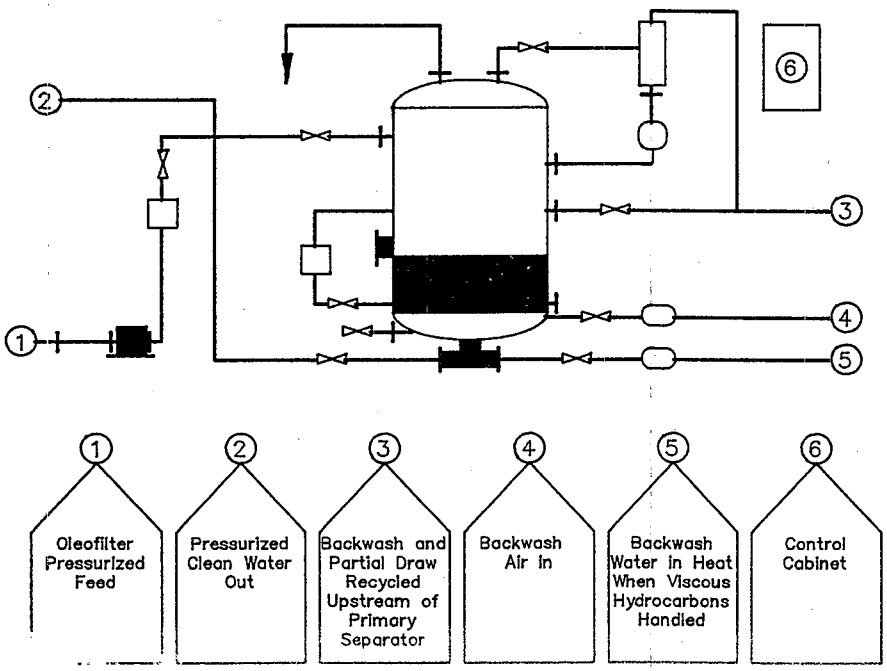
This hydrocarbon recovery technology is based on an oleophilic amine-coated ceramic chip that separates suspended and dissolved hydrocarbons, and mechanical and some chemical emulsions from aqueous solutions. The oleophilic chip is manufactured by grafting a hydrophobic amine to a mineral support, in this case a ceramic substrate. Each granule is 0.6 to 1 millimeter in diameter, but is very porous and thus has a large surface area. The hydrophobic property of the amine coating makes each granule more electrochemically attractive to hydrocarbons in an unstable emulsion.

The figure below illustrates the process. The pressure-sensitive filtering bed is regenerated by automatic backflushing. This automatic regeneration eliminates the expense associated with regeneration of carbon and similar filtration media. Recovered hydrocarbons are coalesced and can thus be removed by simple gravity separation

Treatment systems incorporating this technology have been designed for various applications, including the following:

- Contaminated groundwater pump-and-treat systems
- In-process oil and water separation
- Filtration systems
- Combined oil and water separator-filter-coalescer system for on-site waste reduction and material recovery
- Treatment of marine wastes (bilge and ballast waters)

This technology provides cost-effective oil and water separation, removes free and emulsified hydrocarbon contaminants, recovers up to 90 percent of the dissolved hydrocarbons, and significantly reduces hydrocarbon loading to air strippers and carbon systems. The technology can achieve a concentration of less than 7 parts per million oil and grease in the treated effluent.



Schematic Diagram of the Oleofilter Technology

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The amine-coated granules have proven effective on a wide variety of hydrocarbons, including gasoline; crude oil; diesel fuel; benzene, toluene, ethylbenzene and xylene compounds; and polynuclear aromatic hydrocarbons. The unit removes chlorinated hydrocarbons such as pentachlorophenol, polychlorinated biphenyls, and trichloroethene, as well as vegetable and animal oils.

STATUS:

This technology was accepted into the SITE Demonstration Program in December 1992. The SITE demonstration was completed in June 1994 at the Petroleum Products Corporation site in Fort Lauderdale, Florida. Detailed demonstration results will be available in late 1994.

The technology has been used on several full-scale projects. Several separator-filter-coalescers are in use treating industrial process waters and oily washwaters.

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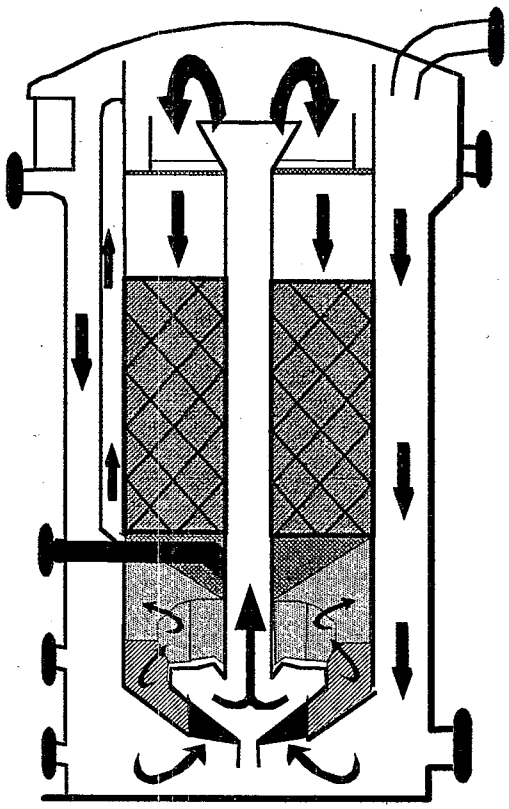


Separator, Filter, and Coalescer

NOVATERRA, INC.
(formerly TOXIC TREATMENTS USA, INC.)
(In Situ Steam and Air Stripping)

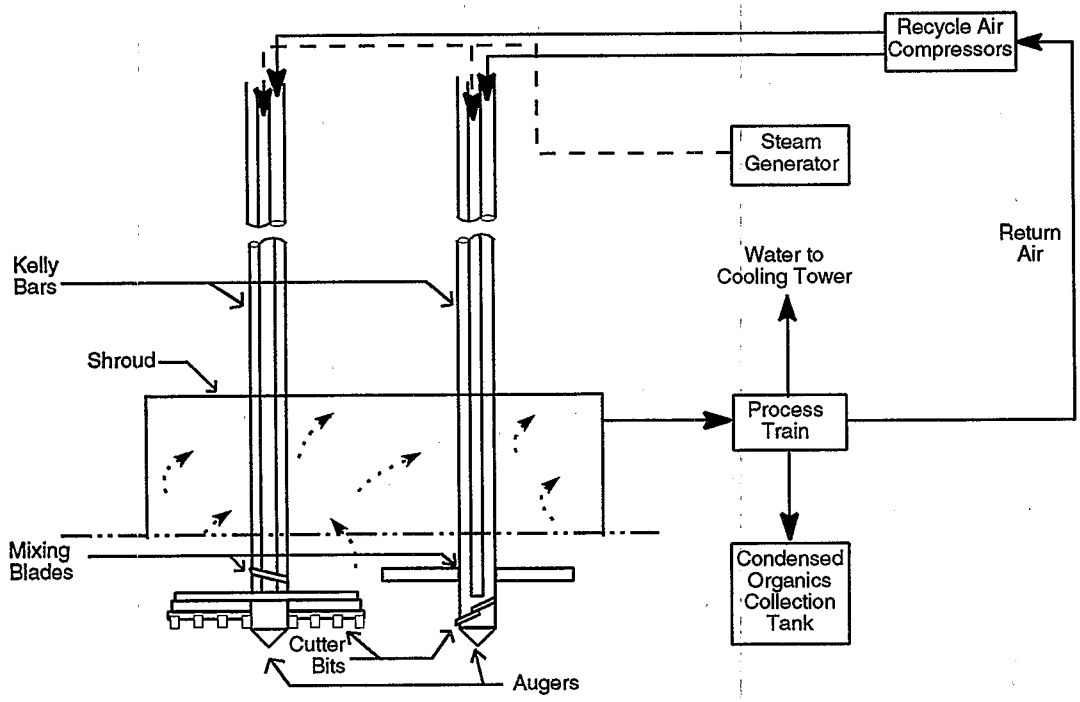
TECHNOLOGY DESCRIPTION:

This technology uses a transportable treatment unit called the Detoxifier™ for in situ steam and air stripping of volatile organic compounds (VOC) from contaminated soil. The two main components of the treatment unit are the process tower and process train (see figure below). The process tower contains two counter-rotating hollow-stem drills, each with a modified cutting bit 5 feet in diameter, capable of operating to a 33-foot depth.

Each drill contains two concentric pipes. The inner pipe conveys steam to the rotating cutting blades. The steam is supplied by an oil- or natural gas-fired boiler at 450 degrees Fahrenheit (°F) and 450 pounds per square inch gauge (psig). The outer pipe conveys air at about 300 °F and 250 psig to the rotating blades. Steam and air are delivered to the top of the drills and injected into the soil through perforations in the cutting blades. The steam heats the soils, increasing the vapor pressure of the volatile contaminants and the rate at which they can be stripped. Volatile and semivolatile organic compounds form low boiling point azeotropes with steam, which significantly increases removal efficiency.

Both the air and steam convey these contaminants to the surface. A metal box, called a shroud, seals the process area above the rotating cutter blades from the outside environment. A blower removes the contaminant-laden air and steam from the shroud, creating a vacuum that carries the air and steam to the process train.

In the process train, the volatile contaminants and the water vapor are removed from the off-gas stream by condensation. The condensed water is separated from the contaminants by distillation, then filtered through activated carbon beds and subsequently used as make-up



Detoxifier™ Process Schematic

The SITE Program assesses but does not approve or endorse technologies.

water for a wet cooling tower. Steam regenerates the activated carbon beds and provides heat for distilling the volatile contaminants from the condensed liquid stream. The recovered concentrated organic liquid can be recycled or used as an incinerator fuel.

The Detoxifier™ also treats contaminated soil in situ by injecting a wide range of reactive chemicals into the soil. Chemical injection processes include stabilization/solidification plus neutralization, oxidation, and bioremediation. The dual injection capabilities permit additional versatility; each kelly bar can deliver two materials to the augers for injection into the soil. The injection systems replace the process train and are mounted on the same chassis that supports the Detoxifier™ drilling tower.

WASTE APPLICABILITY:

This technology can treat VOCs, including hydrocarbons and solvents, with sufficient vapor pressure in the soil. The technology is not limited by soil particle size, initial porosity, chemical concentration, or viscosity. The technology also significantly reduces the concentration of semivolatile organic compounds (SVOC) in soil, primarily by forming steam-organic azeotropes. This technology also treats inorganics, heavy metals, and mixed wastes with stabilization and solidification.

STATUS:

A SITE demonstration was performed in September 1989 at the Annex Terminal, San Pedro, California. Twelve soil blocks were treated for VOCs and SVOCs. Liquid samples were collected during the demonstration, and the operating procedures were closely monitored and recorded. In January 1990, six blocks that had been previously treated in the saturated zone were analyzed by EPA methods 8240 and 8270. The Applications Analysis Report (EPA/540/A5-90/008) was published in June 1991. The technology has successfully been used at five other contaminated sites.

DEMONSTRATION RESULTS:

The SITE technology demonstration yielded the following results:

- Removal efficiencies were greater than 85 percent for VOCs present in the soil.
- Removal efficiencies were greater than 55 percent for SVOCs present in the soil.
- Fugitive air emissions from the process were very low.
- No downward migration of contaminants resulted from the soil treatment.
- The process treated 3 cubic yards of soil per hour.

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The SITE Program assesses but does not approve or endorse technologies.

RESOURCES CONSERVATION COMPANY
(B.E.S.T. Solvent Extraction Technology)

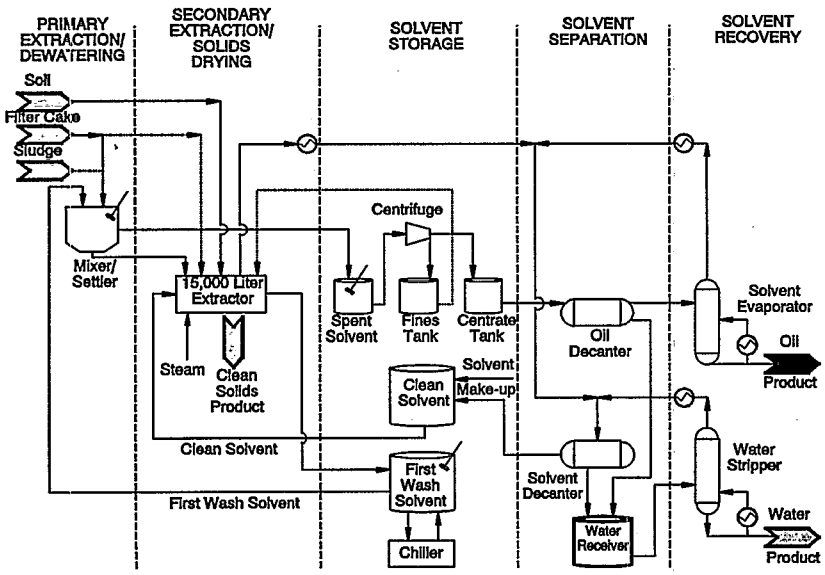
TECHNOLOGY DESCRIPTION:

Solvent extraction treats sludges, sediments, and soils contaminated with a wide range of hazardous contaminants including polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons (PAH), pesticides, and herbicides. The waste matrix is separated into three fractions: oil, water, and solids. As the fractions separate, organic contaminants are concentrated in the oil fraction. For example, PCBs are concentrated in the oil fraction, while metals are separated into the solids fraction. The volume and toxicity of the original waste is thereby reduced, and the concentrated waste streams can be efficiently treated for disposal.

The B.E.S.T. technology is a mobile solvent extraction system that uses amines (usually triethylamine) to separate organics from soils and sludges. Triethylamine is hydrophobic above 20 degrees Celsius (°C) and hydrophilic below 20 °C. This property allows the process to extract both aqueous and nonaqueous compounds by simply changing the solvent's temperature.

Because triethylamine is flammable in the presence of oxygen, the treatment system must be sealed from the atmosphere and operated under a nitrogen blanket. Before treatment, the waste material's pH must be raised to greater than 10 so that triethylamine may be conserved and recycled. The pH may be adjusted by adding sodium hydroxide. Pretreatment also includes screening the waste to remove particles larger than 1 inch in diameter.

The B.E.S.T. process begins by mixing and agitating the cold solvent and waste in a cold extraction tank (see figure below). Solids from the cold extraction tank are then transferred to the extractory dryer vessel. Hydrocarbons and water in the waste simultaneously solubilize with the triethylamine, creating a homogeneous mixture. As the solvent breaks the oil-water-solid emulsions in the waste, the solids are released and settle by gravity. The solvent



B.E.S.T. Solvent Extraction Technology

The SITE Program assesses but does not approve or endorse technologies.

mixture is decanted from the solids and centrifuged to remove fine particles.

The solvent-oil-water mixture is then heated. As the mixture's temperature increases, the water separates from the organics and solvent. The organics-solvent fraction is decanted and sent to a solvent evaporator, where the solvent is recycled. The organics are discharged for recycling or disposal. The water passes to a steam stripping column where residual solvent is recovered for recycling. The water is typically discharged to a local wastewater treatment plant.

The B.E.S.T. technology is modular, allowing for on-site treatment. The process significantly reduces the hydrocarbon concentration in the solids. B.E.S.T. also concentrates the contaminants into a smaller volume, allowing for efficient final treatment and disposal.

WASTE APPLICABILITY:

The B.E.S.T. technology can remove hydrocarbon contaminants, such as PCBs, PAHs, pesticides, and herbicides from sediments, sludges, or soils. System performance can be influenced by the presence of detergents and emulsifiers, low pH materials, and reactivity of the organics with the solvent.

STATUS:

The B.E.S.T. technology was accepted into the SITE Demonstration Program in 1987. The SITE demonstration was completed in July 1992 at the Grand Calumet River site in Gary, Indiana. The following reports are available from EPA:

- Applications Analysis Report (EPA/540/AR-92/079)
- Technology Evaluation Report - Vol I (EPA/540/R-92/079a)
- Technology Evaluation Report - Vol II, Part 1 (EPA/540/R-92/079b)
- Technology Evaluation Report - Vol II, Part 2 (EPA/540/R-92/079c)
- Technology Evaluation Report - Vol II, Part 3 (EPA/540/R-92/079d)
- Technology Demonstration Summary (EPA/540/SR-92/079)

The first full-scale B.E.S.T. unit was used at the General Refining Superfund site in Garden City, Georgia. Solvent extraction is the selected remedial action at the Ewan Property site in New Jersey, the Norwood PCBs site in Massachusetts, and is also the preferred alternative at the F. O'Connor site in Maine.

DEMONSTRATION RESULTS:

The demonstration showed that the B.E.S.T. process could remove greater than 99 percent PCBs (treated solids contained less than 2 milligrams per kilogram PCBs) found in river sediments without using mechanical dewatering equipment. Comparable removal efficiencies were noted for PAHs.

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The SITE Program assesses but does not approve or endorse technologies.

RETECH, INC.
(Plasma Arc Vitrification)

TECHNOLOGY DESCRIPTION:

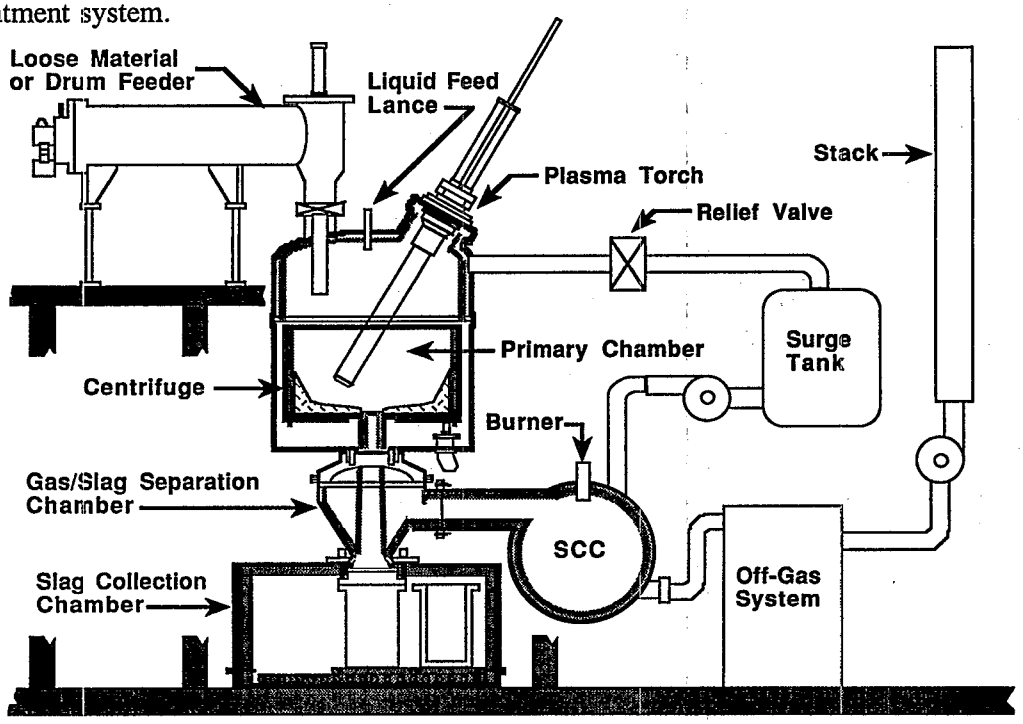
Plasma arc vitrification treatment occurs in a plasma arc centrifugal treatment (PACT) furnace, where heat from a transferred plasma arc torch creates a molten bath that detoxifies the feed material. Solids melt and are vitrified in the molten bath, while metals are retained in this phase. When cooled, the resulting product is a nonleachable, glassy residue which meets toxicity characteristic leaching procedure (TCLP) criteria.

Waste material is fed into a sealed centrifuge where solids are heated to approximately 3,200 degrees Fahrenheit (°F) and gas temperature is maintained at a minimum of 1,800 °F by a plasma torch. Organic material is evaporated and destroyed. Off-gases travel through a gas-slag separation chamber to a secondary combustion chamber, where the temperature is maintained at over 2,000 °F for about 2 seconds. The off-gases then flow through an off-gas treatment system.

Inorganic material is reduced to a molten phase that is uniformly heated and mixed by the centrifuge and the plasma arc. Material can be added in-process to control slag quality. When the centrifuge slows, the molten material is discharged as a homogeneous, nonleachable, glassy slag into a mold or drum in the slag collection chamber.

The off-gas treatment system removes particulates, organic vapors, and volatilized metals. Off-gas monitoring verifies that all applicable environmental regulations are met. The design of the off-gas treatment system depends on the waste material.

The entire system is hermetically sealed and operated below atmospheric pressure to prevent leakage of process gases. Pressure relief valves connected to a closed surge tank provide relief if gas pressures in the furnace exceed safe levels. Vented gas is held in the tank and recycled into the furnace.



Plasma Arc Centrifugal Treatment (PACT) Furnace

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The technology can process organic and inorganic wastes. It is most appropriate for mixed, transuranic, and chemical plant wastes; soil containing both heavy metals and organics; incinerator ash; and munitions, sludge, and hospital waste.

Waste may be loose (shredded or flotation process) or contained in 55-gallon or 200-liter drums. It can be in almost any physical form: liquid, sludge, metal, rock, or sand. Mercury in the waste is recovered by the off-gas treatment system.

STATUS:

The PACT-6 furnace, formerly PCF-6, was demonstrated under the SITE Program in July 1991 at the Component Development and Integration Facility of the U.S. Department of Energy in Butte, Montana. During the demonstration, the furnace processed about 4,000 pounds of waste. The waste consisted of heavy metal-bearing soil from Silver Bow Creek Superfund site spiked with 28,000 parts per million (ppm) zinc oxide, 1,000 ppm hexachlorobenzene, and a 90-to-10 weight ratio of No. 2 diesel oil. All feed and effluent streams were sampled. The Demonstration Bulletin (EPA/540/M5-91/007), Applications Analysis Report (EPA/540/A5-91/007), and Technology Evaluation Report (EPA/540/5-91/007b) are available from EPA. During subsequent testing at the Component Development and Integration Facility, the PACT-6 furnace achieved the following results:

- Hexachlorobenzene was at or below detection limits in all off-gas samples. The minimum destruction removal efficiency ranged from 99.9968 percent to greater than 99.9999 percent.
- The treated material met TCLP standards for organic and inorganic constituents.
- The treated material contained a high percentage of metals in the feed soil.
- Particulates in the off-gas exceeded the regulatory standard. The off-gas treatment system is being modified accordingly. Particulate emissions from another PACT-8 furnace in Switzerland were measured at 1/200th of the U.S. regulatory limit.
- Nitrous oxide (NO_x) levels met U.S. requirements, but can meet stricter standards. The NO_x concentration in the off-gas from the PACT-8 furnace in Switzerland was reduced to 19 ppm.

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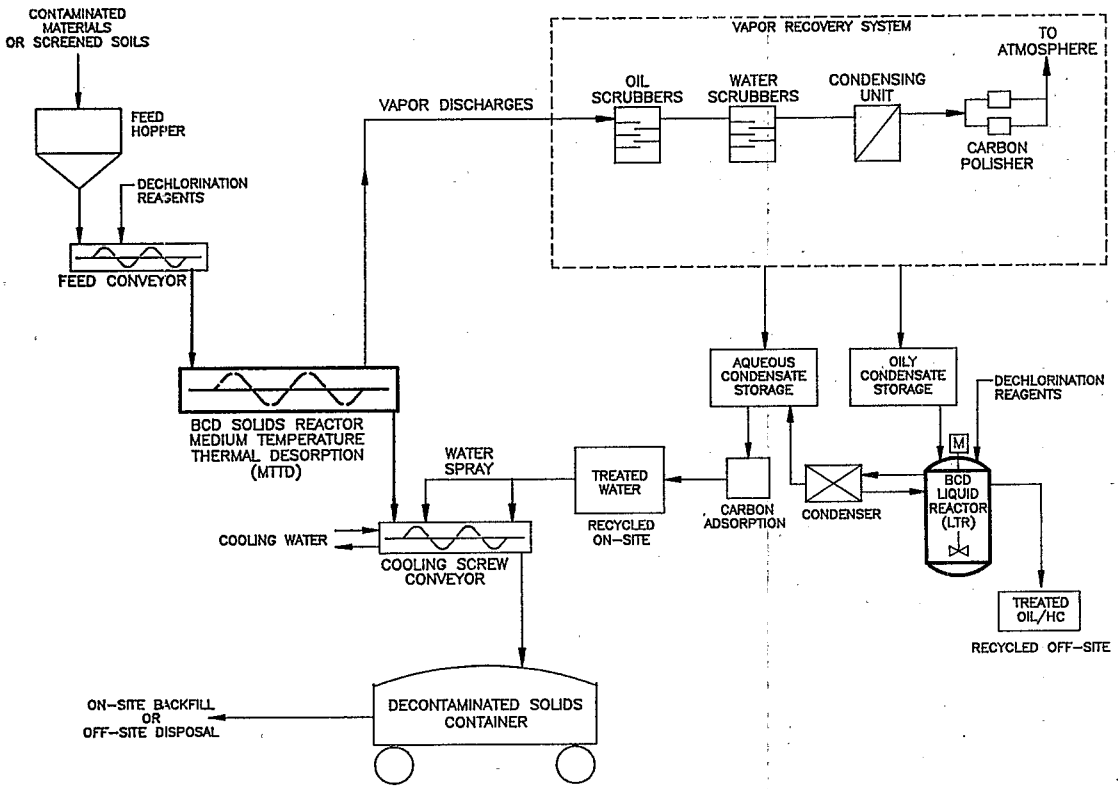
The SITE Program assesses but does not approve or endorse technologies.

RISK REDUCTION ENGINEERING LABORATORY
(Base-Catalyzed Decomposition Process)

TECHNOLOGY DESCRIPTION:

The base-catalyzed decomposition (BCD) process is a chemical dehalogenation technology developed by the Risk Reduction Engineering Laboratory in Cincinnati, Ohio. BCD is initiated in a medium temperature thermal desorber (MTTD), at temperatures ranging from 600 to 950 degrees Fahrenheit (°F). Chemicals are added to contaminated soils, sediments, or sludge matrices containing hazardous chlorinated organics including polychlorinated biphenyls (PCB) and polychlorinated dioxins and furans. BCD then chemically detoxifies the condensed organic contaminants by removing chlorine from the contaminant and replacing it with hydrogen. Because the chlorinated organics have some volatility, there is a degree of volatilization that takes place in parallel with chemical dechlorination. The result is a clean, inexpensive, permanent remedy where all process residuals (including dehalogenated organics) are recyclable or recoverable.

ETG Environmental, Inc. (ETG), and Separation and Recovery Systems (SRS) developed the THERM-O-DETOX® and SAREX® systems and combined them with the BCD process chemistry. The combined process begins by initiating solid phase dechlorination in the MTTD step (see figure below). Organics are thermally desorbed from the matrix, and are condensed and sent to the BCD liquid tank reactor. Reagents are then added and heated to 600 to 650 °F for 1 to 3 hours to dechlorinate the remaining organics. The treated residuals are recycled or disposed of using standard, commercially available methods, including solvent reuse and fuel substitution. Treated, clean soil can be recycled as on-site backfill.



Base-Catalyzed Dechlorination (BCD) Process

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The BCD process can treat soils, sediments, and sludges contaminated with the following chlorinated compounds:

- Halogenated volatile organic compounds
- Halogenated semivolatile organic compounds, including herbicides and pesticides
- PCBs
- Pentachlorophenol (PCP)
- Polychlorinated dioxins and furans

STATUS:

The combined BCD process was successfully demonstrated at the Koppers Company Superfund Site in Morrisville, North Carolina, from August through September 1993. The process removed PCP and polychlorinated dioxins and furans from clay soils to levels well below those specified in the Record of Decision. As a result, EPA Region 4 approved BCD for the full-scale site remediation.

For information on the SAREX® system, see the SRS profile in this document.

DEMONSTRATION RESULTS:

The demonstration consisted of four replicate test runs in the MTTD and two replicate test runs in the liquid tank reactor (LTR). Feed soil consisted of a dry, clayey silt which was processed at a rate of 250 pounds per hour in the MTTD at 800 °F; retention time was approximately one hour. The oil in each LTR test run was batch-processed for six hours at 650 °F.

Based on preliminary analytical results, key findings from the SITE demonstration are summarized as follows:

- The MTTD removed 99 percent of penta-chlorophenol (PCP), and 92 percent of dioxins and furans in the soil.
- Treated soil met the cleanup goals of 95 parts per million for PCP and 7 parts per billion for dioxins and furans.
- All semivolatile organic compounds were well below toxicity characteristic leaching procedure limits in treated soil.
- The LTR batch tests reduced PCP concen-trations by 97 percent, and dioxin and furan concentrations by 99 percent.

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The SITE Program assesses but does not approve or endorse technologies.

RISK REDUCTION ENGINEERING LABORATORY
(Volume Reduction Unit)

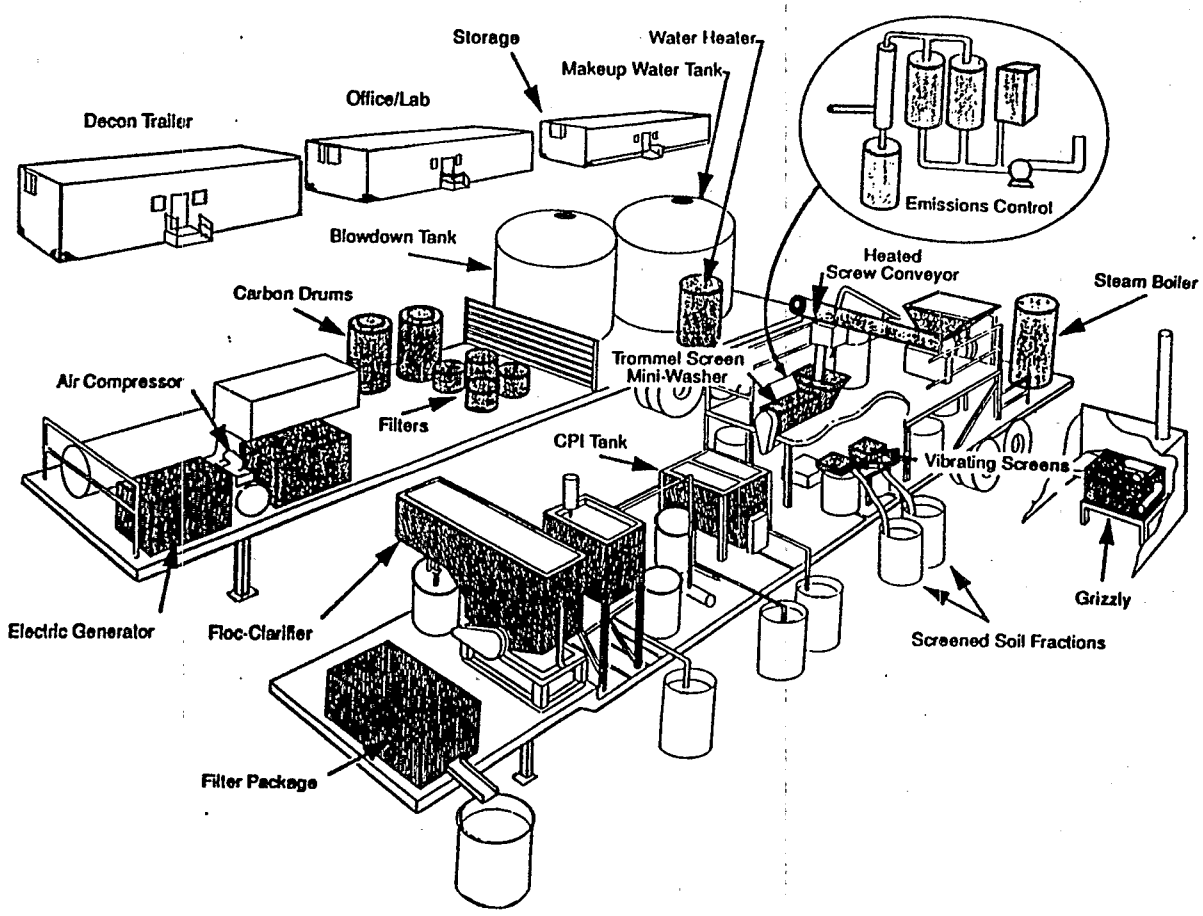
TECHNOLOGY DESCRIPTION:

The volume reduction unit (VRU) is a pilot-scale, mobile soil washing system designed to remove organic contaminants from soil through particle size separation and solubilization. The VRU can process 100 pounds of soil (dry weight) per hour.

The process subsystems include soil handling and conveying, soil washing and coarse screening, fine particle separation, flocculation/clarification, water treatment, and utilities. The VRU is controlled and monitored with conventional industrial process instrumentation and hardware.

WASTE APPLICABILITY:

The VRU can treat soils that contain organics such as creosote, pentachlorophenol (PCP), pesticides, polynuclear aromatic hydrocarbons (PAH), volatile organic compounds, semivolatile organic compounds, and metals.



Typical VRU Operational Setup

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

The VRU was accepted into the SITE Demonstration Program in summer 1992. The demonstration was conducted in November 1992 at the former Escambia Treating Company in Pensacola, Florida. The facility used PCP and creosote PAHs to treat wood products from 1943 to 1982. The Applications Analysis Report (EPA/540/AR-93/508) is available from EPA.

DEMONSTRATION RESULTS:

During the demonstration, the VRU operated at a feed rate of approximately 100 pounds per hour and a wash water-to-feed ratio of about 6 to 1. The following physical wash water conditions were created by varying the surfactant, pH, and temperature:

- Condition 1 - no surfactant, no pH adjustment, no temperature adjustment
- Condition 2 - surfactant addition, no pH adjustment, no temperature adjustment
- Condition 3 - surfactant addition, pH adjustment, and temperature adjustment

The table below summarizes the preliminary analytical data.

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	Condition (%)		
	1	2	3
Average PCP Removal	80	93	97
Average PAH Removal	79	84	96
Feed soil returned as washed soil	96	96	81
Mass balance of total mass	104	113	98
Mass balance of PCPs	108	60	24
Mass balance of PAHs	87	60	17

Preliminary Data

The SITE Program assesses but does not approve or endorse technologies.

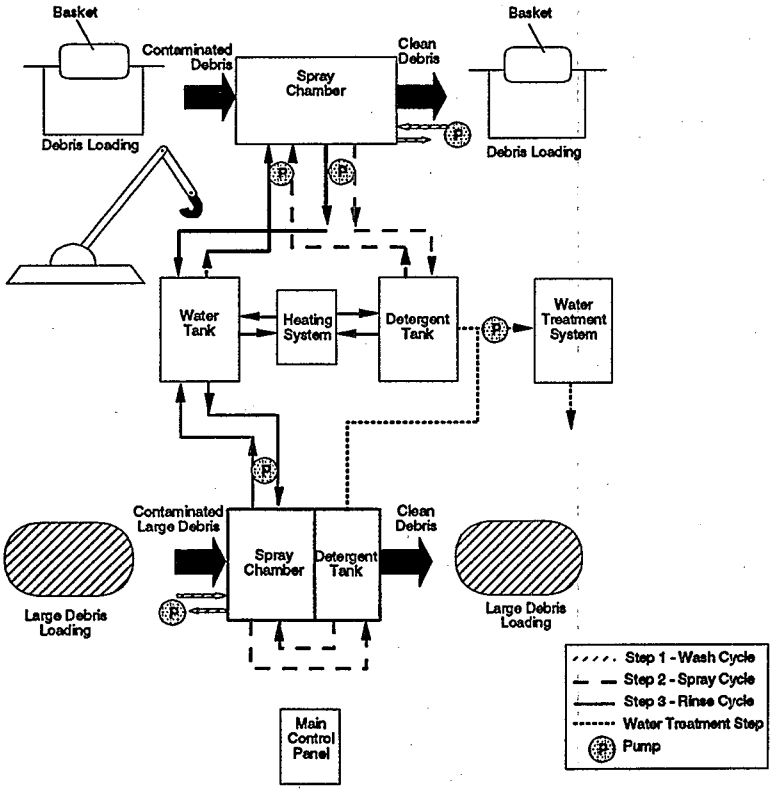
RISK REDUCTION ENGINEERING LABORATORY AND IT CORPORATION
(Debris Washing System)

TECHNOLOGY DESCRIPTION:

This technology was developed by EPA's Risk Reduction Engineering Laboratory (RREL) and IT Corporation (IT) for on-site decontamination of metallic and masonry debris at Comprehensive Environmental Response, Compensation and Liability Act sites. The full-scale debris washing system (DWS) consists of dual 4,000-gallon spray-wash chambers that are connected to a detergent solution holding tank and rinse water holding tank. Debris is placed into one of two 1,200-pound baskets, which in turn is placed into one of the spray-wash chambers using a 5-ton crane integral to the DWS. If debris pieces are large enough, the crane places the debris directly into one of the two chambers. Process water is heated to 160 degrees Fahrenheit using a diesel-fired, 2,000,000-British-thermal-unit-per-hour (Btu/hr) water heater and is continuously reconditioned using particulate filters, an oil/water separator, and other devices such as charcoal columns or ion exchange columns. About 8,000 to 10,000 gallons of water is required for the decontamination process. The system is controlled by an operator stationed in a trailer-mounted control room. The entire system is mounted on three 48-foot flatbed semi-trailers and can be readily transported from site to site.

WASTE APPLICABILITY:

The DWS can be applied on site to various types of debris (scrap metal, masonry, or other solid debris such as stones) contaminated with hazardous chemicals such as pesticides, dioxins, polychlorinated biphenyls (PCB), or hazardous metals.



Pilot-Scale Debris Washing System

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

The first pilot-scale tests were performed in September 1988 at the Carter Industrial Superfund site in Detroit, Michigan. PCB reductions averaged 58 percent in batch 1 and 81 percent in batch 2. Design changes based on these tests were made to the DWS before additional field testing.

An upgraded pilot-scale DWS was tested at a PCB-contaminated Superfund site in Hopkinsville, Kentucky, in December 1989. PCB levels on the surfaces of metallic transformer casings were reduced to less than or equal to 10 micrograms PCB per 100 square centimeters ($\mu g/cm^2$). All 75 contaminated transformer casings on site were decontaminated to EPA cleanup criteria and sold to a scrap metal dealer.

The DWS was also field tested in August 1990 at the Shaver's Farm Superfund site in Walker County, Georgia. The contaminants of concern were benzonitrile and Dicamba. After being cut into sections, 55-gallon drums were decontaminated in the DWS. Benzonitrile and Dicamba levels on the drum surfaces were reduced from the average pretreatment concentrations of 4,556 and 23 $\mu g/100\ cm^2$ to average concentrations of 10 and 1 $\mu g/100\ cm^2$, respectively.

Results have been published in a Technology Evaluation Report (EPA/540/5-91/006a), entitled "Design and Development of a Pilot-Scale Debris Decontamination System."

A manual version of the full-scale DWS was used to treat PCB-contaminated scrap metal at the Summit Scrap Yard in Akron, Ohio.

During the 4-month site remediation, 3,000 tons of PCB-contaminated scrap metal (motors, cast iron blocks) were cleaned on site. The target level of 7.7 $\mu g/100\ cm^2$ or less was met, in most cases, after a single treatment with the DWS. The cleaned scrap was purchased by a scrap smelter for $52/ton. The net costs for the on-site debris decontamination ranged from $50 to $75 per ton.

The automated, trailer-mounted DWS is scheduled for deployment to a hazardous waste site in The Netherlands for an initial demonstration of the new system. RREL and IT estimate that the system can decontaminate 50 to 120 tons of typical debris per day.

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The SITE Program assesses but does not approve or endorse technologies.

RISK REDUCTION ENGINEERING LABORATORY and USDA FOREST PRODUCTS LABORATORY
(Fungal Treatment Technology)

TECHNOLOGY DESCRIPTION:

This biological treatment system uses white rot fungi to treat soils in situ. These lignin-degrading fungi bioremediate certain organic contaminants.

Organic materials inoculated with the fungi are mechanically mixed into the contaminated soil. Using enzymes normally produced for wood degradation as well as other enzyme systems, the fungi break down soil contaminants.

Because this technology uses a living organism, the greatest degree of success occurs with optimal growing conditions. Moisture control is necessary, and temperature and aeration may also be controlled. Organic nutrients such as peat may be added to soils deficient in organic carbon.

WASTE APPLICABILITY:

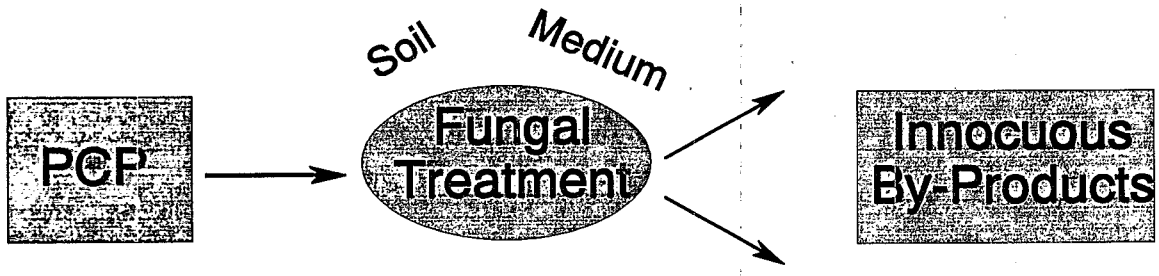
This biological treatment system was initially developed to treat soil contaminated with chemicals found in the wood preserving industry. These contaminants include chlorinated organics and polynuclear aromatic hydrocarbons (PAH). The system may remediate different contaminants and combinations of contaminants with varying degrees of success. In particular, the SITE Demonstration Program evaluated how well white rot fungi degrades pentachlorophenol (PCP) in combination with creosote PAHs.

STATUS:

This biological treatment system was accepted into the SITE Demonstration Program in April 1991. In September 1991, a treatability study was conducted at the Brookhaven Wood Preserving site in Brookhaven, Mississippi. Site soils were contaminated with 700 parts per million (ppm) PCP and 4,000 ppm PAH. Study results showed that one lignin-degrading fungus removed 89 percent of PCP and 70 percent of total PAHs during a 2-month period.

A full-scale demonstration of this fungus was completed in November 1992 to obtain economic data. The Demonstration Bulletin (EPA/540/MR-93/505) is available from EPA.

The full-scale project involved a 1/4-acre plot of contaminated soil and two smaller control plots. The soil was inoculated with *Phanaerochaete sordida*, a species of white rot fungus. No woodchips or other bulking agents were added to the prepared soil. Field activities included tilling and watering all plots. No nutrients were added.



In Situ White Rot Fungal Treatment of Contaminated Soil

The SITE Program assesses but does not approve or endorse technologies.

Air emissions data showed no significant hazards to field technicians due to soil tilling activities. Contaminated soil, underlying sand, and leachate had no significant contamination.

Initial results showed a 70 percent reduction in contaminants, both in the plot containing the fungal treatment and in the plot containing a nonfungal, organic amendment. Unidentified, indigenous fungal species may have significantly reduced contaminants in the nonfungal plot. About 13 percent of contamination was removed from the nonamended (soil-only) control plot.

DEMONSTRATION RESULTS:

Some key findings from the demonstration are as follows:

- Levels of PCP and the target PAHs found in the underlying sand layer and the leachate from each of the plots were insignificant, indicating low leachability and loss of these contaminants due to periodic irrigation of the soil and heavy rainfall.
- Levels of PCP, the target PAHs, and dioxins in the active air samples collected during the soil tilling events were insignificant, indicating a very low potential for airborne contaminant transport.

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The SITE Program assesses but does not approve or endorse technologies.

RISK REDUCTION ENGINEERING LABORATORY, THE UNIVERSITY OF CINCINNATI, and FRX, INC.
(Hydraulic Fracturing)

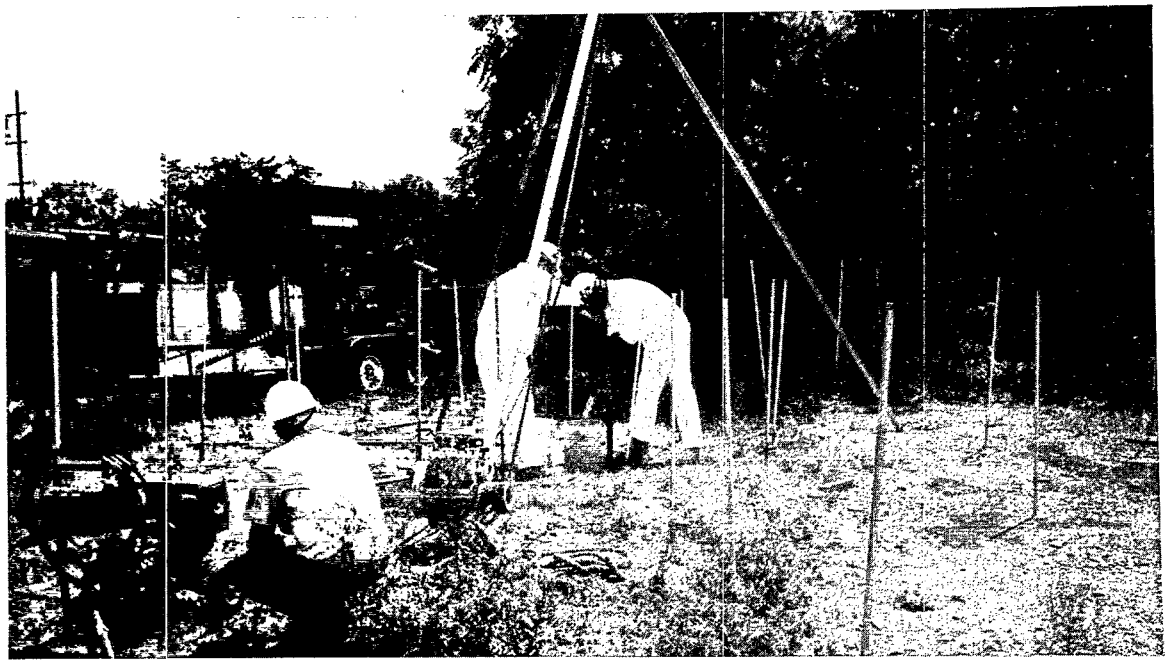
TECHNOLOGY DESCRIPTION:

Hydraulic fracturing is a physical process that creates fractures in soils to enhance fluid or vapor flow in the subsurface. The technology places fractures at discreet depths with hydraulic pressurization at the base of a borehole. These fractures are placed at specific locations and depths to increase the effectiveness of treatment technologies such as soil vapor extraction, in situ bioremediation, and pump-and-treat systems. The technology is designed to enhance remediation in less permeable geologic formations.

The fracturing process begins by injecting water into a sealed borehole until the water pressure exceeds a critical value and a fracture is nucleated (see photograph below). A slurry composed of a coarse-grained sand, or other granular material, and guar gum gel is then injected as the fracture grows away from the well. After pumping, the grains hold the fracture open while an enzyme additive breaks down the viscous fluid. The thinned fluid is pumped from the fracture, forming a permeable subsurface channel suitable for delivering or recovering a vapor or liquid. These fractures function as pathways for fluid movement, potentially increasing the effective area available for remediation.

The hydraulic fracturing process is used in conjunction with soil vapor extraction technology to enhance recovery of contaminated soil vapors. Hydraulic fractures have recently been used to improve recovery of light non-aqueous phase liquids by increasing recovery of free product and controlling the influence of underlying water. Hydraulically-induced fractures are used as channels for fluids and nutrients during in situ bio-remediation. The technology has the potential to deliver solids useful in bioremediation to the subsurface. Solid nutrients or oxygen-releasing granules can be injected into the fractures.

Real time techniques for measuring ground surface deformation have been developed to monitor the fracture positions in the subsurface.



Hydraulic Fracturing Process (Well is at Center of Photograph)

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

Hydraulic fracturing is appropriate for enhancing soil and groundwater remediation. The technology can channel contaminants or wastes for soil vapor extraction, bioremediation, or pump-and-treat systems.

STATUS:

The hydraulic fracturing technology entered the SITE Demonstration Program in July 1991. Demonstrations have been conducted in Oak Brook, Illinois, and Dayton, Ohio. The hydraulic fracturing process has been integrated with soil vapor extraction at the Illinois site and with in situ bioremediation at the Ohio site. The project was completed in September 1992. The Technology Evaluation and Applications Analysis reports were published under one cover (EPA/540/R-93/505). The Technology Demonstration Summary (EPA/540/SR-93/505) is also available. FRX, Inc., has conducted additional demonstrations of hydraulic fractures.

DEMONSTRATION RESULTS:

The first demonstration was conducted at a Xerox Corporation site in Oak Brook, Illinois, where a vapor extraction system has been operating since early 1991. The site is contaminated with ethylbenzene, 1,1-dichloroethane, trichloroethene, tetrachloroethane, 1,1,1-trichloroethane, toluene, and xylene. In July 1991, hydraulic fractures were created in two of the four wells, at depths of 6, 10, and 15 feet below ground surface. The vapor flow rate, soil vacuum, and contaminant yields from the fractured and unfractured wells were monitored regularly. Results from this demonstration are as follows:

- Over a one year period, the vapor yield from hydraulically fractured wells was one order of magnitude greater than from unfractured wells.
- The hydraulically fractured wells enhanced remediation over an area 30 times greater than the unfractured wells.
- The presence of pore water decreased the vapor yield from wells; therefore, water must be prevented from infiltrating areas where vapor extraction is underway.

The technology was also demonstrated at a site near Dayton, Ohio, where in situ bioremediation was cleaning up an underground storage tank spill. The site is contaminated with benzene, toluene, ethylbenzene, and xylene (BTEX), and other petroleum hydrocarbons. In August 1991, hydraulic fractures were created in one of two wells at 4, 6, 8, and 10 feet below ground surface. Sampling was conducted before the demonstration and twice during the demonstration at locations 5, 10, and 15 feet north of the fractured and unfractured wells. Results from this demonstration are as follows:

- The flow of water into the fractured well was two orders of magnitude greater than in the unfractured well.
- The bioremediation rate near the fractured well was 75 percent higher for BTEX and 77 percent higher for total petroleum hydrocarbons compared to the rates near the unfractured well.

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The SITE Program assesses but does not approve or endorse technologies.

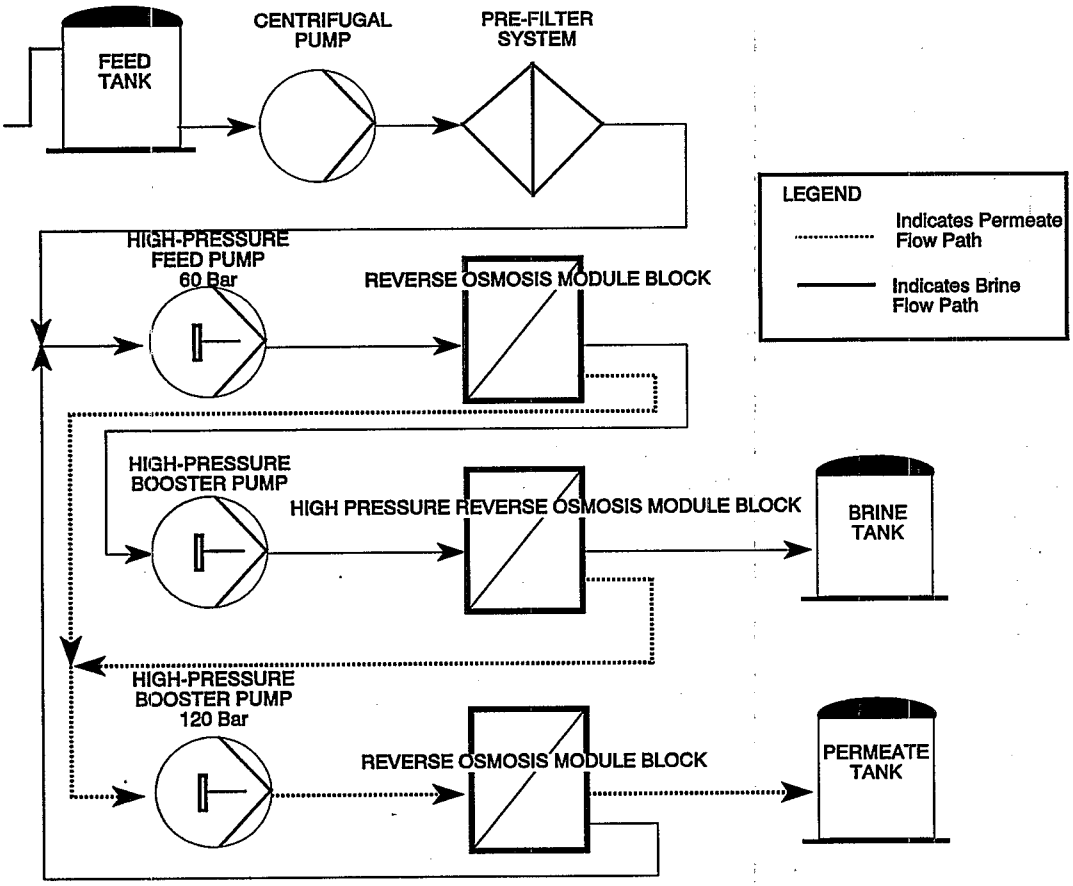
ROCHEM SEPARATION SYSTEMS, INC.
(Rochem Disc Tube™ Module System)

TECHNOLOGY DESCRIPTION:

The Rochem Disc Tube™ Module System uses membrane separation to treat aqueous solutions ranging from seawater to leachate contaminated with organic solvents. The system uses osmosis through a semipermeable membrane to separate pure water from contaminated liquids.

Osmotic theory implies that a saline solution may be separated from pure water by a semipermeable membrane. The higher osmotic pressure of the salt solution (because of its higher salt concentration) causes the water (and other compounds having high diffusion rates through the selected membrane) to diffuse through the membrane into the salt water. Water will continue to permeate into the salt solution until the osmotic pressure of the salt solution equals the osmotic pressure of the pure water. At this point, the salt concentrations of the two solutions are equal, eliminating any additional driving force for mass transfer across the membrane. However, if an external pressure is exerted on the salt solution, water will flow in the reverse direction from the salt solution into the pure water.

This phenomenon, known as reverse osmosis (RO), can separate pure water from contaminat-



Three Stage Reverse Osmosis Flow Path Diagram

The SITE Program assesses but does not approve or endorse technologies.

ed matrices. RO can treat hazardous wastes by concentrating the hazardous chemical constituents in an aqueous brine, while recovering pure water on the other side of the membrane.

Fluid dynamics and system construction result in an open-channel, fully turbulent feed and water-flow system. This configuration prevents accumulation of suspended solids on the separation membranes, ensuring high efficiency filtration for water and contaminants. Also, the design of the disc tubes allows for easy cleaning of the filtration medium, providing a long service life for the system's membrane components.

A general schematic of the RO equipment as it will be applied at the SITE demonstration is provided in the figure on the previous page. Waste feed, process permeate, and rinsewater are potential feed materials to the RO modules. The modules are skid-mounted and consist of a tank and a high-pressure feed system. The high-pressure feed system consists of a centrifugal feed pump, a prefilter cartridge housing, and a triplex plunger pump to feed the RO modules. The processing units are self-contained and need only electrical and interconnection process piping before operation.

WASTE APPLICABILITY:

Many types of waste material can be treated with this system, including sanitary and hazardous landfill leachate containing both organic and inorganic chemical species.

STATUS:

This technology was accepted into the SITE Demonstration Program in July 1991. A Demonstration was conducted in August 1994 at the Central Landfill Superfund Site in Johnston, Rhode Island. The system cleaned up landfill leachate from a hazardous waste landfill. During the demonstration, approximately 4 gallons per minute of contaminated waste was processed over a 3-week period. All feed and residual effluent streams were sampled to evaluate the performance of this technology. Results from the demonstration will be available in spring 1995.

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The SITE Program assesses but does not approve or endorse technologies.

RUST REMEDIAL SERVICES, INC.
(formerly offered by CHEMICAL WASTE MANAGEMENT, INC.)
(X*TRAX™ Thermal Desorption)

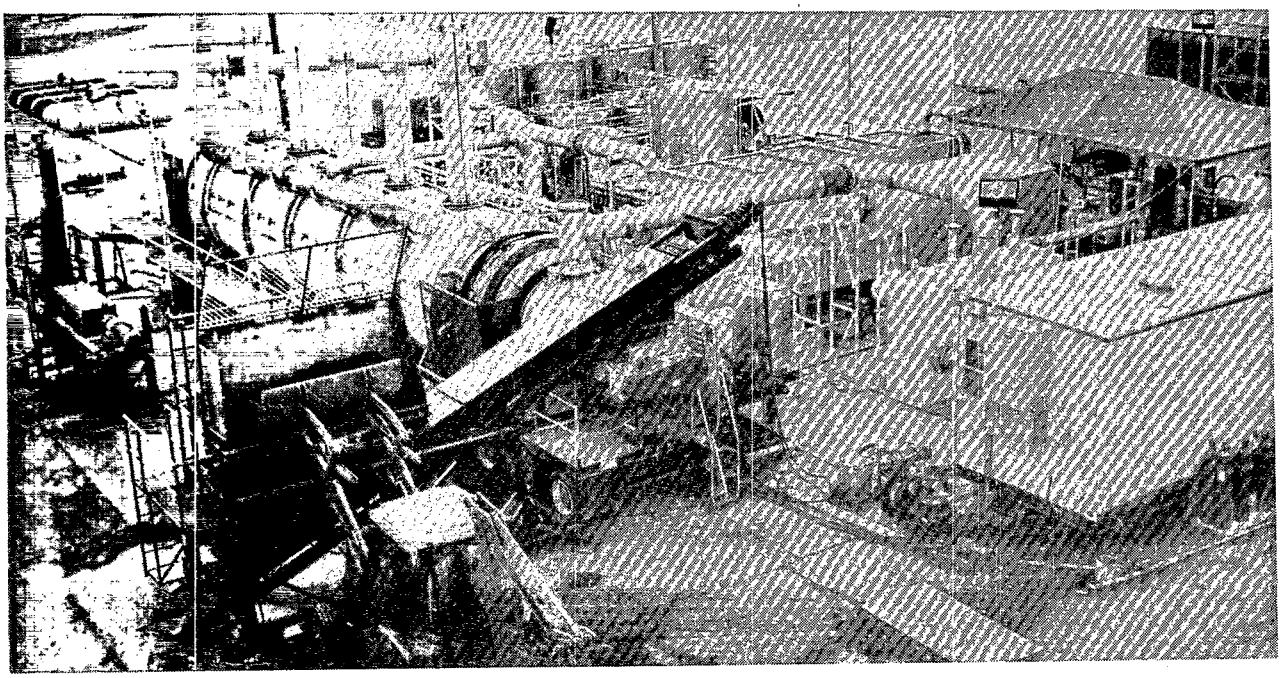
TECHNOLOGY DESCRIPTION:

The X*TRAX™ technology is a patented thermal desorption process that removes organic contaminants from soils, sludges, and other solid media (see photograph below). X*TRAX™ is not, however, an incinerator or a pyrolysis system. Chemical oxidation and reactions are discouraged by maintaining an inert environment and low treatment temperatures. Combustion by-products are not formed in X*TRAX™, as neither a flame nor combustion gases are present in the desorption chamber.

The organic contaminants are removed as a condensed liquid, which is characterized by a high heat rating. This liquid may then be destroyed in a permitted incinerator or used as a supplemental fuel. Because of low operating temperatures of 400 to 1,200 degrees Fahrenheit (°F) and low gas flow rates, this process offers cost effective treatment of contaminated media.

An externally-fired rotary dryer volatilizes the water and organic contaminants from the contaminated media into an inert carrier gas stream. The processed solids are then cooled with water to eliminate dusting. The solids can then be replaced and compacted in their original locations.

The inert nitrogen carrier gas transports the organic contaminants and water vapor out of the dryer. It flows through a duct to the gas treatment system, where organic vapors, water vapors, and dust particles are removed and recovered. The gas first passes through a high-energy scrubber, which removes dust particles and 10 to 30 percent of the organic contaminants. The gas then passes through two condensers in series, where it is cooled to less than 40 °F.



Full-Scale X*TRAX™ System

The SITE Program assesses but does not approve or endorse technologies.

Most of the carrier gas is reheated and recycled to the dryer. About 5 to 10 percent of the gas is separated from the main stream, passed through a particulate filter and a carbon adsorption system, and then discharged to the atmosphere. This discharge allows addition of make-up nitrogen to the system to keep oxygen concentrations below 4 percent (typically below 1 percent). The discharge also helps maintain a small negative pressure within the system and prevents potentially contaminated gases from leaking. The volume of gas released from this process vent is approximately 700 times less than an equivalent capacity incinerator.

WASTE APPLICABILITY:

The X*TRAX™ process removes 1) chlorinated and non-chlorinated volatiles and semi-volatiles, such as solvents, polychlorinated biphenyls (PCB), and dioxins; 2) organics; and 3) heavy metals such as mercury, from soils, sludges, and sediments. X*TRAX™ has successfully removed PCBs from soil in a full-scale demonstration; bench- and pilot-scale systems have removed a variety of contaminants from soils, sludges, and sediments. In most cases, volatile organics are reduced to below 1 part per million (ppm), and frequently to below the laboratory detection level. Semivolatile organics are typically reduced to less than 10 ppm and frequently below 1 ppm. Soils containing 120 to 24,000 ppm PCB have been reduced to less than 2 ppm. Removal efficiencies from 96 to over 99 percent have been demonstrated for soils contaminated with various organic pesticides. Mercury has been reduced from 5,100 ppm to 1.3 ppm. For most materials, the system can process 120 to 280 tons per day.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1989. The full-scale X*TRAX™ system, Model 200, successfully remediated 53,000 tons of PCB-contaminated soil at the Re-Solve, Inc., Superfund site in Massachusetts. The system has treated up to 280 tons of soil per day to less than 2 ppm PCB; the site's treatment standard is 25 ppm. EPA conducted a SITE demonstration in May 1992, during this remediation. During the demonstration, the system operated reliably. Average PCB concentrations in the treated soils were 0.13 milligrams per kilogram; no dioxins or dibenzofurans were formed during treatment. The vent gas met all appropriate permit requirements and emitted less than 0.4 grams of organics per day to the atmosphere. The Applications Analysis Report will be published in late 1994.

RUST Remedial Services currently has laboratory-, pilot-, and full-scale X*TRAX™ systems. Two laboratory-scale, continuous pilot systems are available for treatability studies. Both systems are operated at RUST's Clemson Technical in South Carolina: one treats mixed Resource Conservation and Recovery Act (RCRA)/radioactive wastes; the other treats RCRA and Toxic Substances Control Act wastes. More than 108 tests have been completed since January 1988.

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The SITE Program assesses but does not approve or endorse technologies.

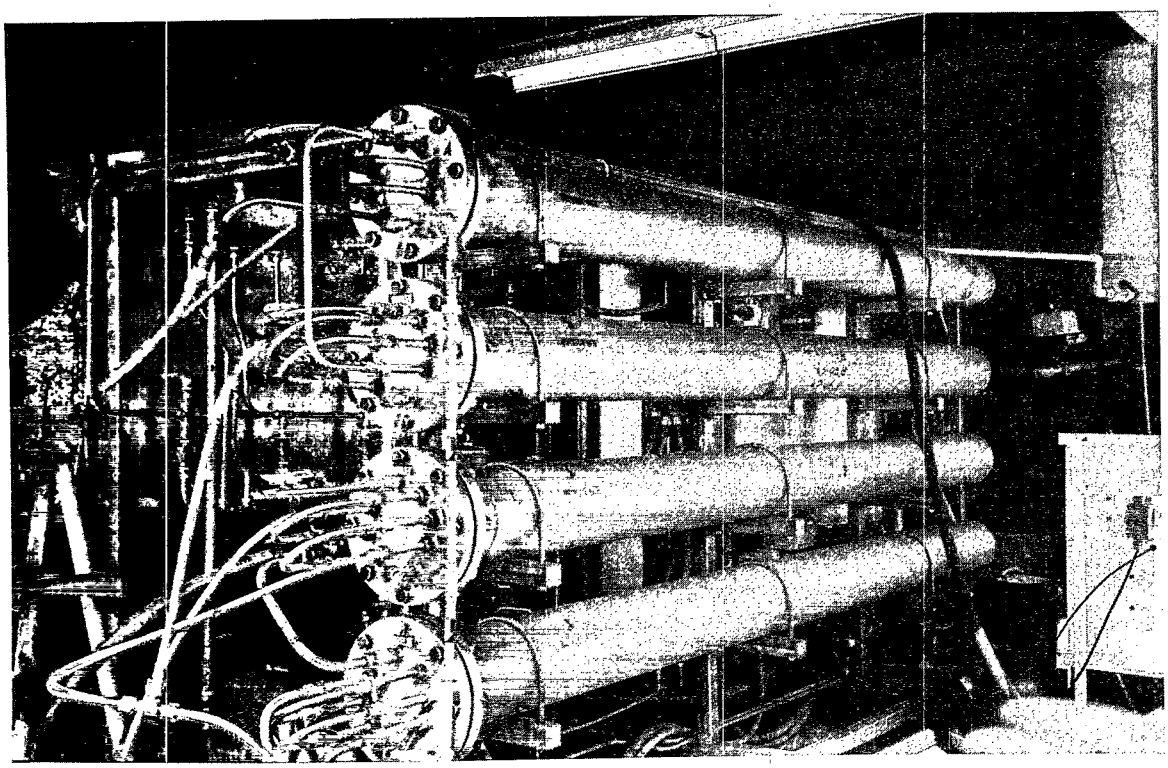
SBP TECHNOLOGIES, INC.
(Membrane Filtration and Bioremediation)

TECHNOLOGY DESCRIPTION:

SBP Technologies, Inc. (SBP), has developed a hazardous waste treatment system consisting of 1) a membrane filtration unit that extracts and concentrates contaminants from groundwater, surface water, wash water, or slurries, and 2) a bioremediation system that treats concentrated groundwater, wash water, and soil slurries (see photograph below). These two systems treat a wide range of waste materials separately or as parts of an integrated waste handling system.

The membrane filtration unit removes and concentrates contaminants by pumping contaminated liquids through porous stainless-steel tubes coated with specifically formulated membranes. Contaminants are collected inside the tube membrane, while "clean" water permeates the membrane and tubes. Depending on local requirements and regulations, the clean permeate can be discharged to the sanitary sewer for further treatment at a publicly owned treatment works (POTW). The concentrated contaminants are collected in a holding tank and fed to the bioreactor system.

Contaminated water or slurry can also feed directly into the bioreactor and be polished with the membrane filtration unit. The bioreactor, or series of bioreactors, are inoculated with specially-selected, usually indigenous microorganisms to produce effluent with low to nondetectable contaminant levels. Integrating the two units allows removal and destruction of many contaminants.



Membrane Filtration and Bioremediation

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The membrane filtration system concentrates contaminants and reduces the volume of contaminated materials from a number of waste streams, including contaminated groundwater, surface water, storm water, landfill leachates, and industrial process wastewater.

The bioremediation system can treat a wide range of organic contamination, especially wood-preserving wastes and solvents. A modified version can also treat polynuclear aromatic hydrocarbons (PAH) such as creosote and coal tar; pentachlorophenol; petroleum hydrocarbons; and chlorinated aliphatics, such as trichloroethene.

The two technologies can be used separately or combined, depending on site characteristics and waste treatment needs. For example, on wastewaters or slurries contaminated with inorganics or materials not easily bioremediated, the membrane filtration unit can separate the material for treatment by another process. Both the membrane filtration system and the bioremediation system can be used as part of a soil cleaning system to handle residuals and contaminated liquids.

STATUS:

The membrane filtration system, accepted into the SITE Program in 1990, was demonstrated in October 1991 at the American Creosote Works in Pensacola, Florida.

A full-scale SITE Program demonstration of the bioremediation system was cancelled. However, a smaller-scale field study was conducted at the site; results are available through the developer. A demonstration bulletin describing the membrane filtration performance is available (EPA/540/MR-92/014) from EPA.

SBP is marketing its bioremediation and membrane filtration systems to industrial and governmental clients for on-site treatment of contaminated soil, sludge, and water.

DEMONSTRATION RESULTS:

Results from the SITE demonstration are summarized as follows:

- The system effectively concentrated the PAHs into a smaller volume.
- The process removed 95 percent of the PAHs found in creosote from the feed and produced a permeate stream that was acceptable for discharge to a publicly owned treatment works facility.
- The membrane removed 25 to 35 percent of smaller phenolic compounds.
- The system removed an average of about 80 percent of the total concentrations of creosote constituents (phenolics and PAHs) in the feedwater and permeate.

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The SITE Program assesses but does not approve or endorse technologies.

J.R. SIMPLOT
(The SABRE™ Process)

TECHNOLOGY DESCRIPTION:

Anaerobic microbial mixtures have been discovered that degrade both dinoseb (2-sec-butyl-4,6-dinitrophenol) and trinitrotoluene (TNT). These microbes completely degrade their target molecules to simple nonaromatic products within a few days.

The Simplot Anaerobic Biological Remediation (SABRE™) process offers reduced liability from on-site bioremediation of soils contaminated with the pesticide dinoseb or nitroaromatic explosives. The biodegradation process begins when contaminated soil is placed in a bioreactor with water in a one-to-one ratio by weight. Small amounts of phosphorus buffers, a source of carbon (a J.R. Simplot potato waste by-product), and a consortium of enhanced nitro-aromatic-degrading anaerobic bacteria are introduced to the bioreactor. The developer continuously monitors the bioreactor temperature, pH, and redox potential.

Mixing systems have been engineered to accommodate most soil types and bioreactor sizes. System design is site-specific and determined by treatability studies.

WASTE APPLICABILITY:

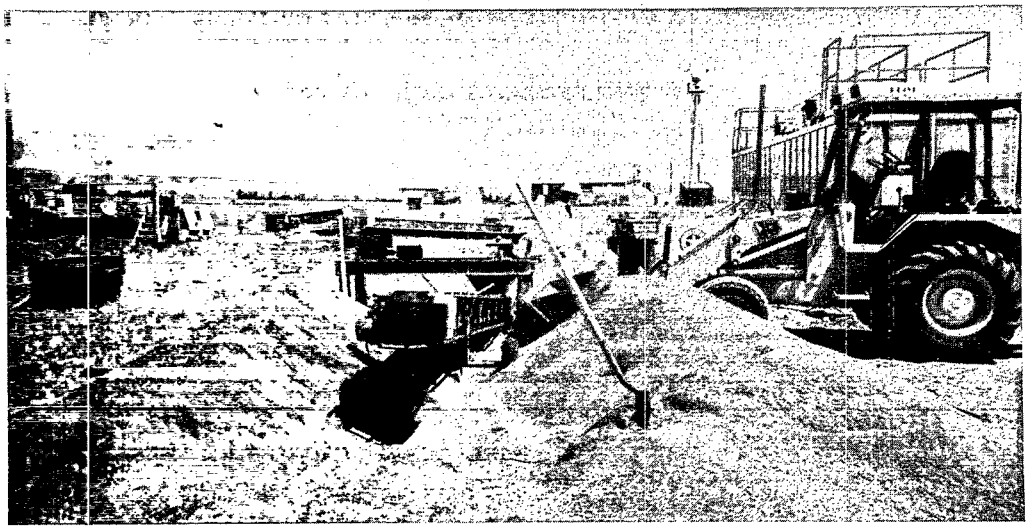
This technology is designed to treat soils contaminated with nitroaromatic pollutants.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in January 1990. Based on bench- and pilot-scale results from the Emerging Technology Program, this technology was accepted in the SITE Demonstration Program in winter 1992.

The technology was demonstrated on TNT at The Weldon Spring Ordnance Works, an abandoned explosives manufacturing site in Weldon Spring, Missouri. The demonstration began in late September 1993 and was completed in February 1994. Final results of the Weldon Spring demonstration will be available in late 1994.

Preliminary results show reductions of TNT from average concentrations of 1507 parts per million (ppm) to an average of 11 ppm, for an average removal rate of 99.27 percent. The Weldon Spring demonstration shows the effec-



The SABRE™ Process for Remediation of Dinoseb at Ellensburg, Washington

The SITE Program assesses but does not approve or endorse technologies.

tiveness of this process even in unfavorable conditions. The demonstration was delayed by unseasonably cool ambient temperatures; temperatures in the bioreactor were as low as 4 degrees Celsius (°C). Ideal temperatures for the Simplot process are from 35 to 37 °C.

The technology was demonstrated on dinoseb at Bowers Field in Ellensburg, Washington, and was completed in July 1993. Detailed demonstration results will be available in late 1994. In the field, dinoseb was reduced from 27.3 ppm to below the detection limit, or a greater than 99.8 percent removal. Other pesticides were also degraded in this process, highlighting the effectiveness of the process even in the presence of co-contaminants. The process was completed in 23 days in spite of 18 °C temperatures. Toxicity studies are being performed on the TNT soil; results are pending.

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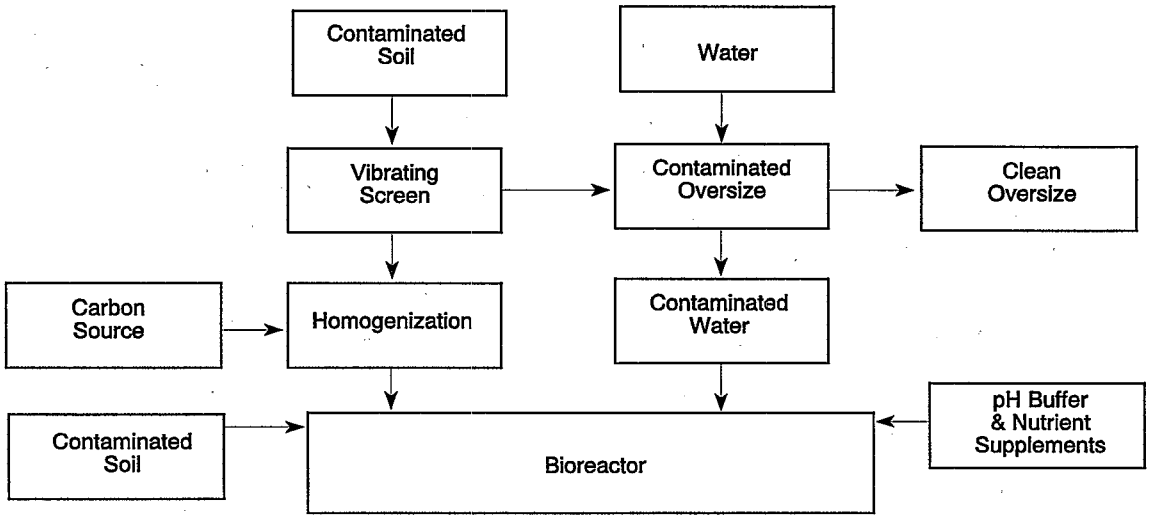


Schematic Diagram of the SABRE™ Process

SOILTECH ATP SYSTEMS, INC.
(Anaerobic Thermal Processor)

TECHNOLOGY DESCRIPTION:

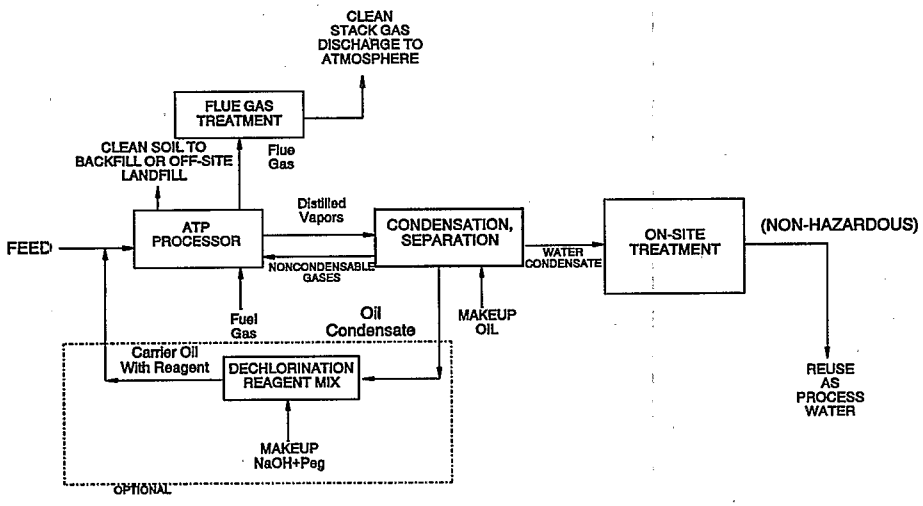
The SoilTech ATP Systems, Inc. (SoilTech), anaerobic thermal processor (ATP) uses a rotary kiln unit to desorb, collect, and recondense contaminants from feed material (see figure below). The ATP can also be used in conjunction with a dehalogenation process to chemically destroy halogenated hydrocarbons at elevated temperatures.

The proprietary kiln contains four separate internal thermal zones: preheat, retort, combustion, and cooling. In the preheat zone, water and volatile organic compounds (VOC) are vaporized. The hot solids and heavy hydrocarbons then pass through a proprietary sand seal to the retort zone. The sand seal allows solids to pass and inhibits gas and contaminant movement from one zone to the other. Concurrently, hot treated soil from the combustion zone enters the retort zone through a second sand seal. This hot treated soil provides the thermal energy necessary to desorb the heavy organic contaminants. The vaporized contaminants are removed under slight vacuum to the gas handling system. After cyclones remove dust from the gases, the gases are cooled, and condensed oil and water are separated into their various fractions.

The coked soil passes through a third sand seal from the retort zone to the combustion zone. Some of the hot treated soil is recycled to the retort zone through the second sand seal as previously described. The remainder of the soil enters the cooling zone.

As the hot combusted soil enters the cooling zone, it is cooled in the annular space between the outside of the preheat zone and the kiln shell. Here, the heat from the combusted soils is transferred indirectly to the soils in the preheat zone. The cooled, treated soil exiting the cooling zone is quenched with water and conveyed to a storage pile.

Flue gases from the combustion zone pass through the cooling zone to an emission control system. The system consists of a cyclone and baghouse to remove particulates, a wet scrubber to remove acid gases, and a carbon adsorption bed to remove trace organic compounds.



Anaerobic Thermal Processor (ATP)

The SITE Program assesses but does not approve or endorse technologies.

When the ATP system dechlorinates contaminants, an oil mixture containing alkaline dehalogenation reagents is sprayed on the contaminated soil as it enters the preheat zone. The reagents dehalogenate or chemically break down chlorinated compounds, including polychlorinated biphenyls (PCB), in the ATP system.

WASTE APPLICABILITY:

The ATP system was originally developed to recover oil from tar sands and shales. The system is now also used to dechlorinate PCBs and chlorinated pesticides in soils and sludges; to separate oils and water from refinery wastes and spills; and, in general, to remove hazardous VOCs and semivolatile organic compounds (SVOC) from soils and sludges. The ATP technology has also been selected to remediate contaminated soil at two Superfund sites contaminated with polynuclear aromatic hydrocarbons, pesticides, dioxins, and furans.

STATUS:

The ATP system has been demonstrated at two sites. At the first demonstration, in May 1991, a full-scale unit dechlorinated PCB-contaminated soil at the Wide Beach Development Superfund site in Brant, New York. At the second demonstration, completed in June 1992, a full-scale unit remediated soils and sediments at the Waukegan Harbor Superfund site in Waukegan, Illinois. The technology has since treated PCB, polychlorinated aromatic hydrocarbons, and pesticide-contaminated soils at two additional Superfund sites. Two additional Superfund sites have since been remediated by the ATP system in Ohio and Kentucky.

DEMONSTRATION RESULTS:

Test results from both SITE demonstrations indicate the following:

- The SoilTech ATP system removed over 99 percent of the PCBs in the contaminated soil, resulting in PCB levels below 0.1 parts per million (ppm) at the Wide Beach Development site and averaging 2 ppm at the Waukegan Harbor Superfund site.
- Dioxin and furan stack gas emissions were below the site-specific standards.
- PCB stack gas emissions were equivalent to 99.9999 percent destruction and removal efficiency at the Waukegan Harbor site.
- No volatile or semivolatile organic degradation products were detected in the treated soil. Also, no leachable metals, VOCs, or SVOCs were detected in the treated soil.
- For the Wide Beach Development and Waukegan Harbor remediation projects, soil treatment costs were approximately $265 and $155 per ton, respectively. The regulatory support, mobilization, startup, and demobilization costs totalled about $1,400,000 for each site.

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The SITE Program assesses but does not approve or endorse technologies.

SOLIDITECH, INC.
(Solidification and Stabilization)

TECHNOLOGY DESCRIPTION:

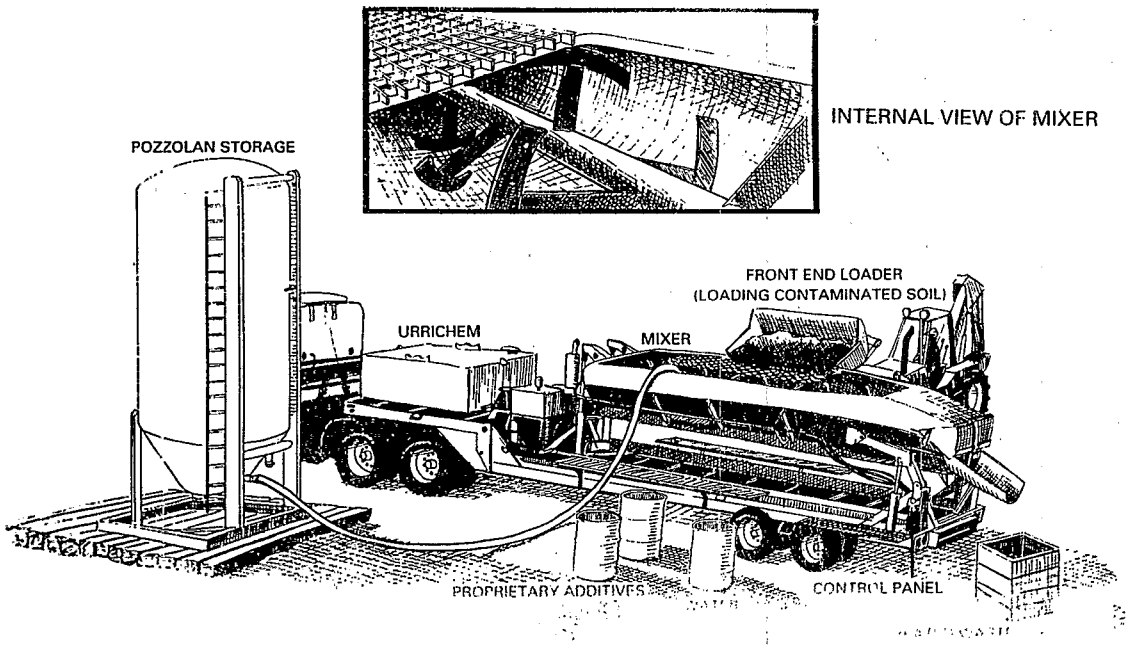
This solidification and stabilization process immobilizes contaminants in soils and sludges by binding them in a concrete-like, leach-resistant matrix. Contaminated waste materials are collected, screened to remove oversized material, and introduced to the batch mixer (see figure below). The waste material is then mixed with water; Urrichem, a proprietary chemical reagent; proprietary additives; and pozzolanic material (fly ash), kiln dust, or cement. After it is thoroughly mixed, the treated waste is discharged from the mixer. Treated waste is a solidified mass with significant unconfined compressive strength (UCS), high stability, and a rigid texture similar to that of concrete.

WASTE APPLICABILITY:

This process treats soils and sludges contaminated with organic compounds, metals, inorganic compounds, and oil and grease. Batch mixers of various capacities can treat different volumes of waste.

STATUS:

The solidification and stabilization process was demonstrated in December 1988 at the Imperial Oil Company/Champion Chemical Company Superfund site in Morganville, New Jersey. This location formerly contained both chemical processing and oil reclamation facilities. Soils, filter cake, and oily wastes from an old storage



Soliditech Processing Equipment

The SITE Program assesses but does not approve or endorse technologies.

tank were treated during the demonstration. These wastes were contaminated with petroleum hydrocarbons, polychlorinated biphenyls (PCB), other organic chemicals, and heavy metals.

A Technology Evaluation Report (EPA/540/5-89/005a), an Applications Analysis Report (EPA/540/A5-89/005), and a Demonstration Bulletin (EPA/540/M5-89/005) are available from EPA. Long-term chemical and physical monitoring and mineralogic analyses are currently underway.

This technology is no longer available through a vendor. Contact the EPA Project Manager for further information.

DEMONSTRATION RESULTS:

Key findings from the Soliditech demonstration are summarized below:

- Extract and leachate analyses showed that heavy metals in the untreated waste were immobilized.
- The process solidified both solid and liquid wastes with high organic content (up to 17 percent), as well as oil and grease.
- Volatile organic compounds in the original waste were not detected in the treated waste.
- Physical test results of the solidified waste showed: 1) UCS ranging from 390 to 860 pounds per square inch (psi); 2) very little weight loss after 12 cycles of wet and dry and freeze and thaw durability tests; 3) low permeability of the treated waste; and 4) increased density after treatment.
- The solidified waste increased in volume by an average of 22 percent. Because of solidification, the bulk density of the waste material increased by about 35 percent.
- Semivolatile organic compounds (phenols) were detected in the treated waste and the toxicity characteristic leaching procedure (TCLP) extracts from the treated waste, but not in the untreated waste or its TCLP extracts. The presence of these compounds is believed to result from chemical reactions in the waste treatment mixture.
- The oil and grease content of the untreated waste ranged from 2.8 to 17.3 percent (28,000 to 173,000 parts per million [ppm]). The oil and grease content of the TCLP extracts from the solidified waste ranged from 2.4 to 12 ppm.
- The pH of the solidified waste ranged from 11.7 to 12.0. The pH of the untreated waste ranged from 3.4 to 7.9.
- PCBs were not detected in any extracts or leachates from the treated waste.
- Visual observation of solidified waste revealed dark inclusions about 1 millimeter in diameter. Ongoing microstructural studies are expected to confirm that these inclusions are encapsulated wastes.

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The SITE Program assesses but does not approve or endorse technologies.

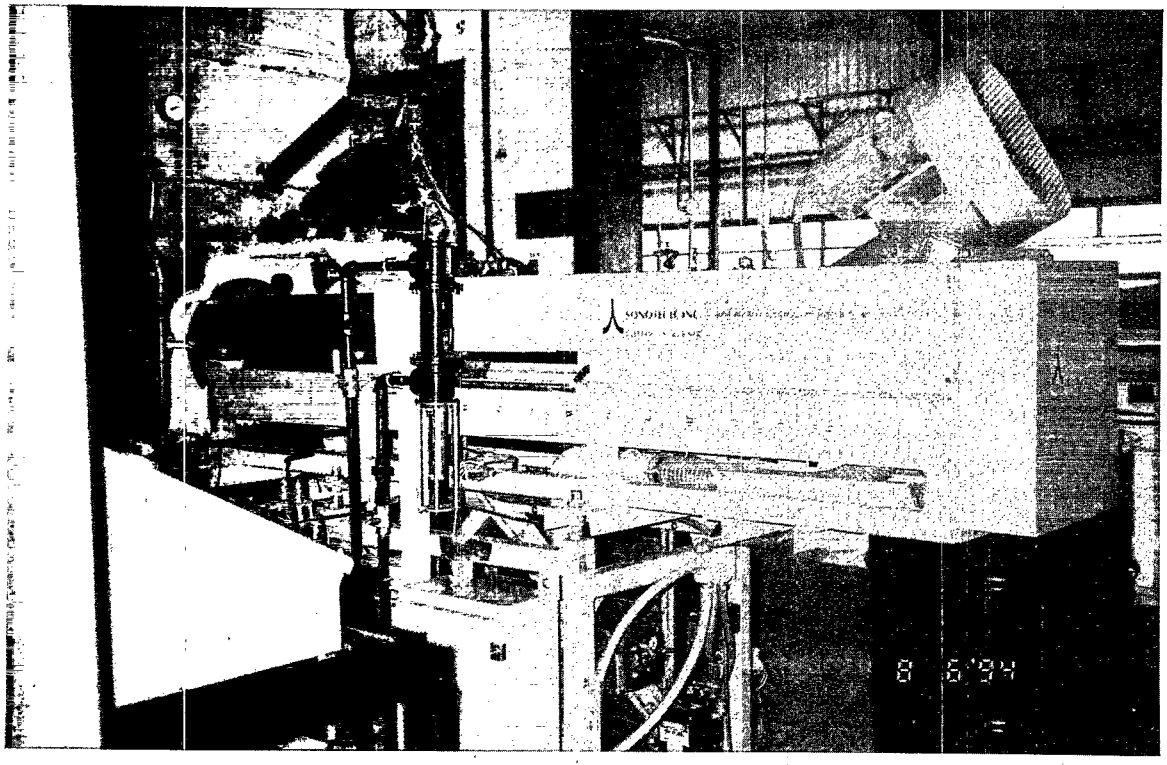
SONOTECH, INC.
(Frequency-Tunable Pulse Combustion System)

TECHNOLOGY DESCRIPTION:

Pulse combustion can potentially improve the performance of various incineration and energy-intensive processes. The Sonotech, Inc., frequency-tunable pulse combustion system (FTPC) can significantly improve batch- and continuous-mode incinerator performance by creating large-amplitude, resonant pulsations inside the incinerator. This technology can be applied to new or existing systems. The technology is proven and used in fossil fuel combustion devices, residential natural gas furnaces, and industrial combustion systems. It should prove to be similarly beneficial to hazardous waste incineration and soil remediation applications.

The FTPC is a burner system that consists of an air inlet, a combustion section or a tailpipe, a control panel, and a safety system (see photograph below). The FTPC improves an incinerator's performance by 1) increasing mixing rates between the fuel and air, 2) increasing mixing rates between reactive gas pockets and ignition sources (for example, flamelets or hot gases), and 3) increasing rates of heat and mass transfer between the gas and the burning waste. These improvements should 1) reduce the amount of excess air required to completely burn the waste, 2) increase destruction and removal efficiencies of principal organic hazardous constituents, 3) minimize the formation of products of incomplete combustion, and 4) eliminate or minimize detrimental emissions or "puffs."

The FTPC can excite axial, transverse, or three-dimensional acoustic mode oscillations within an



Frequency-Tunable Pulse Combustion System Installed at EPA's Incineration Research Facility

The SITE Program assesses but does not approve or endorse technologies.

industrial enclosure. The FTPC has achieved amplitudes as high as 170 decibels and frequencies of 50 to 500 Hertz. The high frequencies and velocities of these gas oscillations help mix the gases in the chamber and reduce or eliminate stratification effects.

The FTPC can function alone or as a supplemental retrofit to an existing combustion system. In the latter application, the FTPC can supply between 2 to 10 percent of energy requirements. After retrofitting, the total fuel supplied to the main burner and the FTPC is generally less than the amount of fuel supplied to the main burner before retrofitting.

WASTE APPLICABILITY:

This technology can be used with any material that can be treated in a conventional incinerator. The technology has improved the incineration of hazardous solid wastes in an EPA small-scale rotary kiln incinerator in Research Triangle Park, North Carolina. Sonotech, Inc., believes that the technology is ready for incineration of contaminated soils and medical waste.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1992. The 6-week demonstration tested whether the technology could improve the performance of larger scale incineration systems. To meet this goal, a pulse combustion retrofit system for EPA's Incineration Research Facility (IRF) in Jefferson, Arkansas was developed, and testing began in summer 1994. Results from the demonstration will be available in early 1995.

The IRF pilot-scale rotary kiln incinerator is larger than EPA's rotary kiln incinerator simulator unit that was previously tested with the FTPC burner. The retrofitted incinerator was used to treat coal-gasification wastes, traditionally incinerated with conventional, steady-state technology using air or oxygen enrichment.

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The SITE Program assesses but does not approve or endorse technologies.

STC OMEGA, INC.
(formerly SILICATE TECHNOLOGY CORPORATION)
(Chemical Fixation/Solidification Treatment Technologies)

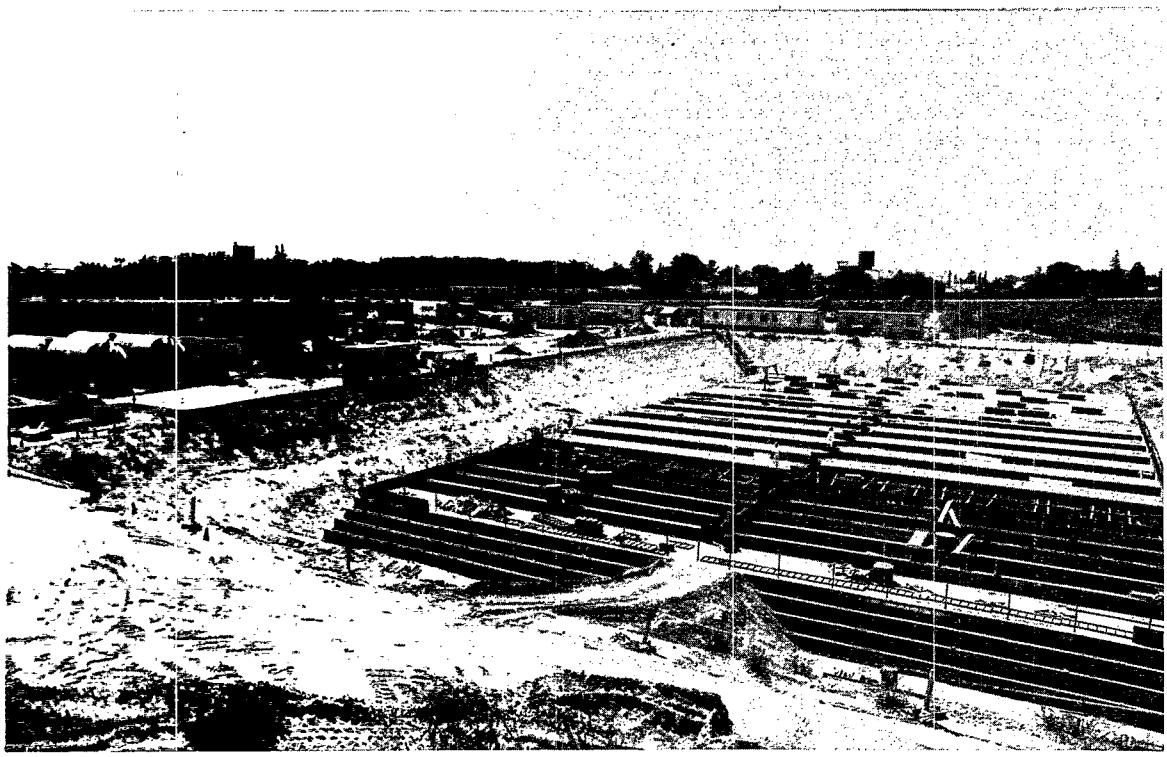
TECHNOLOGY DESCRIPTION:

STC Omega, Inc. (STC Omega), has developed both chemical organic destruction and chemical fixation/solidification technologies that treat inorganic and organic solid hazardous wastes. STC Omega's chemical organic destruction technology oxidizes or dechlorinates selected organic compounds to reduce total contaminant concentrations by more than 95 percent. Leachable organic contaminant concentrations are also reduced to well below regulatory limits.

STC Omega's inorganic contaminant chemical fixation/solidification technology forms insoluble chemical compounds, reducing leachable inorganic contaminant concentrations in soils and sludges. STC Omega's inorganic treatment technologies are more efficient and often less costly than generic cementitious processes.

STC Omega's technology has been successfully implemented on numerous full-scale hazardous waste remediation projects involving up to 100,000 cubic yards of waste. These sites include Superfund sites and industrial sites across the United States and in Italy.

STC Omega has evaluated various materials handling and mixing systems for use on full-scale remediation projects. Materials handling processes include pretreatment processes for screening and crushing contaminated soils, and placement and conveying systems for handling treated material. Mixing systems include various batching plants, pug mills, and high-shear batch mixing systems to properly meter and mix reagents with contaminated soils. STC Omega provides full on-site technical support to ensure effective application of the treatment technologies, documentation, and



Treatment of Contaminated Soil

The SITE Program assesses but does not approve or endorse technologies.

quality assurance/quality control procedures during the treatment process.

WASTE APPLICABILITY:

STC Omega's technology can treat a wide variety of hazardous soils, sludges, and wastewaters, including the following:

- Soils and sludges contaminated with inorganics, including most metals, cyanides, fluorides, arsenates, chromates, and selenium
- Soils and sludges contaminated with organics, including halogenated aromatics, polynuclear aromatic hydrocarbons (PAH), and aliphatic compounds
- Wastewaters contaminated with heavy metals and emulsified and dissolved organic compounds, excluding low-molecular-weight organic contaminants such as alcohols, ketones, and glycols

STATUS:

STC Omega's demonstration project was completed in November 1990 at the Selma Pressure Treating (SPT) Superfund site in Selma, California. STC Omega was subsequently selected for the full-scale remediation of the SPT site, which is contaminated with organics, mainly pentachlorophenol (PCP), and inorganics, mainly arsenic, chromium, and copper. The SPT site was successfully remediated in 1993 using STC Omega's treatment process at a considerable cost savings over competing technologies. The Applications Analysis Report (EPA/540/AR-92/010) and a demonstration videotape are available.

DEMONSTRATION RESULTS:

The demonstration had the following results:

- The STC Omega process reduced total PCP concentrations up to 97 percent. The STC Omega chemical fixation process stabilized the residual PCP concentrations to very low leachable levels (from 5 to less than 0.3 milligrams per liter).
- STC Omega's technology immobilized arsenic and copper, while chromium remained well within regulatory limits.
- The treated wastes had moderately high unconfined compressive strength, averaging 300 pounds per square inch (psi) after 28 days, increasing to more than 700 psi after 18 months.
- Permeability of the treated waste was low (less than 1.7×10^{-7} centimeters per second). The relative cumulative weight loss after 12 wet/dry and 12 freeze/thaw cycles was negligible (less than 1 percent).
- The STC Omega technology's treatment costs depend on specific waste characteristics.

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The SITE Program assesses but does not approve or endorse technologies.

TERRA-KLEEN RESPONSE GROUP, INC.
(Solvent Extraction Treatment System)

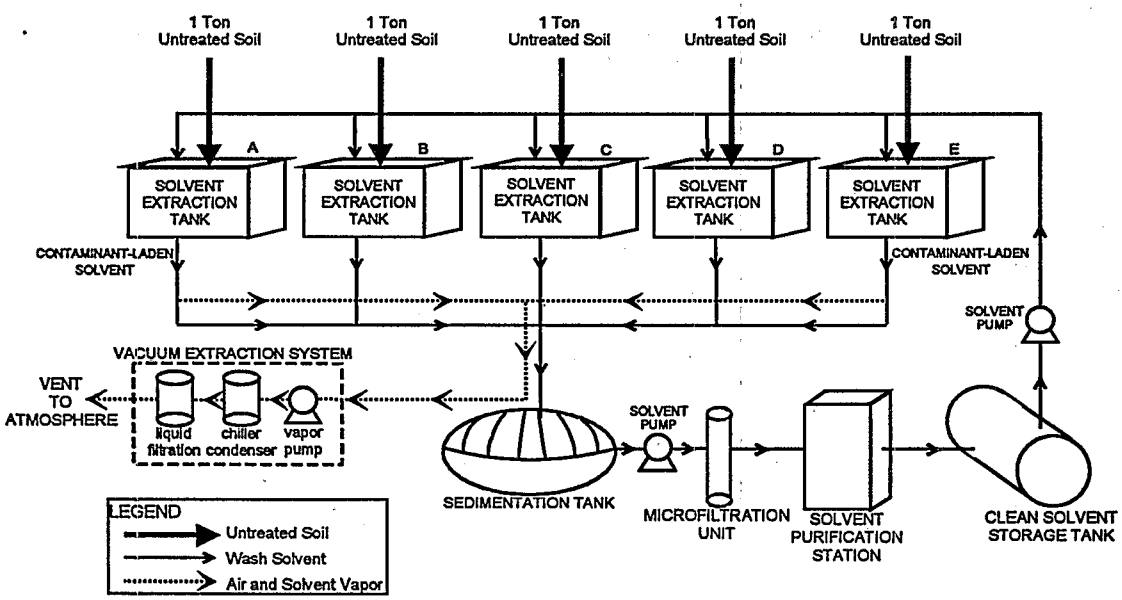
TECHNOLOGY DESCRIPTION:

The solvent extraction treatment system was developed by Terra-Kleen Response Group, Inc. (Terra-Kleen), to remove semivolatile and nonvolatile organic contaminants from soil. This batch process system uses a proprietary solvent blend to separate hazardous constituents from soils, sediments, sludge, and debris. The U.S. EPA Office of Pesticides and Toxic Substances has made a written finding that the Terra-Kleen solvent is nontoxic.

A schematic diagram of the Terra-Kleen treatment system is shown below. Treatment begins after excavated soil is loaded into the extraction tanks. Clean solvent from the solvent storage tank is pumped into the extraction tanks. The soil and solvent mixture is held in the extraction tank for a time period sufficient to solubilize organic contaminants into the solvent, separating them from the soil. The contaminant-laden solvent is then removed from the extraction tanks and pumped into the sedimentation tanks. Suspended solids settle or are flocculated in the sedimentation tank, and are then removed.

Following solvent extraction of the organic contaminants, any residual solvent in the soil is removed using soil vapor extraction and biological treatment. Soil vapor extraction removes the majority of the residual solvent, while biological treatment reduces residual solvent to trace levels. The treated soils are then removed from the extraction tanks.

The solvent regeneration process begins by pumping contaminant-laden solvent from the sedimentation tank through a microfiltration unit and a proprietary solvent purification station. The microfiltration unit first removes any fines remaining in the solvent. The solvent purification station separates organic contaminants from the solvent and concentrates them, reducing the amount of hazardous waste for off-site disposal. The regenerated solvent is pumped into the clean



Solvent Extraction Treatment System

The SITE Program assesses but does not approve or endorse technologies.

solvent storage tank for use in treating additional soil.

WASTE APPLICABILITY:

The Terra-Kleen solvent extraction treatment system is a waste minimization process designed to remove the following organic contaminants from soils: polychlorinated biphenyls (PCB), chlorinated pesticides, polycyclic aromatic hydrocarbons (PAH), pentachlorophenol, creosote, polychlorinated dibenzo-p-dioxins (PCDD), and polychlorinated dibenzofurans (PCDF). The technology also has the capacity to remove organic contaminants, such as PCBs, from low-level radioactive wastes.

The Terra-Kleen solvent extraction system does not require soil screening equipment to remove debris or large objects from the contaminated soil before treatment. The system is transportable and can be configured to treat small quantities of soil (1 to 1,000 cubic yards) as well as large volumes generated at remedial sites.

STATUS:

Terra-Kleen demonstrated its solvent extraction treatment system under the SITE Demonstration Program between May 16 and June 11, 1994. The technology was demonstrated at the Naval Air Station North Island Site 4, in San Diego, California. Soils at Site 4 are contaminated with heavy metals, volatile organic compounds (VOC), semivolatile organic compounds (SVOC) (including PAHs), PCBs (Aroclor 1260), dioxins, and furans.

DEMONSTRATION RESULTS:

Preliminary findings from the Terra-Kleen SITE demonstration are summarized as follows:

- PCB Aroclor 1260 concentrations were reduced from a maximum of 170 milligrams per kilogram (mg/kg) in untreated soil to approximately 2 mg/kg in treated soil. The average removal efficiency was 98.39 percent.
- The system can efficiently concentrate PCBs into a smaller waste volume for off-site disposal.
- The treatment system's PCB removal efficiency was reproducible for all batches run during this demonstration.

To provide additional information on the technology's capabilities, samples were also collected and analyzed for VOCs, SVOCs, PCDD, and PCDF. The analytical data from these samples are not yet available. All findings of the Terra-Kleen SITE demonstration, including sample analytical results, will be discussed in the SITE technology capsule and the innovative technology evaluation report.

Additional data is being collected at the Naval Communication Station in Stockton, California. The system is treating soil contaminated with chlorinated pesticides at concentrations up to 600 mg/kg. Preliminary data indicates that target levels of 1 mg/kg are being achieved.

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The SITE Program assesses but does not approve or endorse technologies.

TERRA VAC, INC.
(In Situ Vacuum Extraction)

TECHNOLOGY DESCRIPTION:

In situ vacuum extraction is a process that removes volatile organic compounds (VOC) from the vadose, or unsaturated soil zone. These compounds can often be removed from the vadose zone before they contaminate groundwater. This extraction process is patented and licensed to Terra Vac, Inc. (Terra Vac), and others.

The extraction process uses readily available equipment, including extraction and monitoring wells, manifold piping, a vapor and liquid separator, a vacuum pump, and an emission control device, such as an activated carbon adsorption filter. After the contaminated area is completely defined, extraction wells are installed and connected by piping to the vacuum extraction and treatment system.

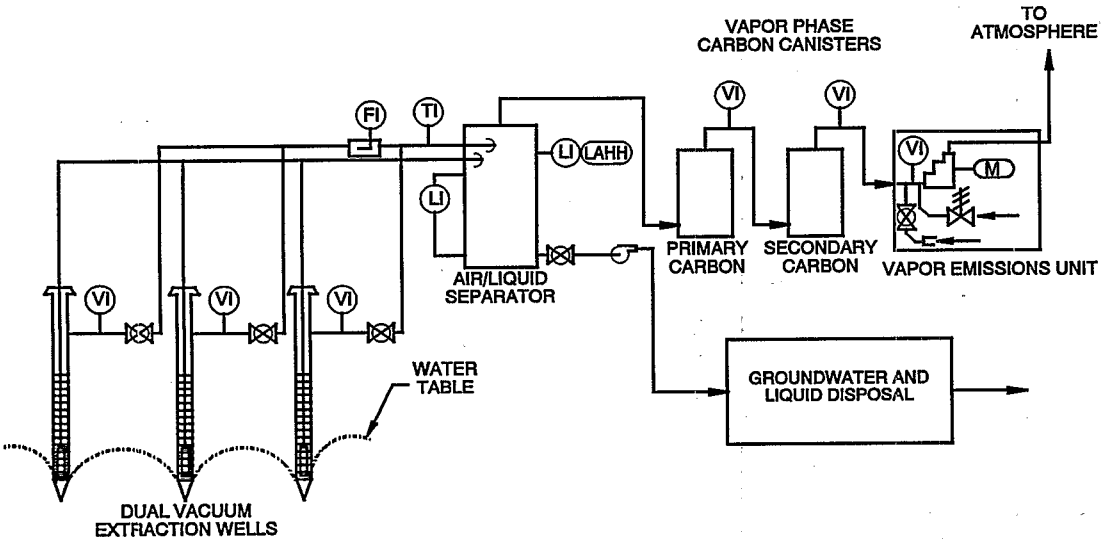
First, a vacuum pump draws the subsurface contaminants from the extraction wells to the liquid/gas separator. The vapor-phase contaminants are then treated with an activated carbon adsorption filter or a catalytic oxidizer before the gases are discharged to the atmosphere. Subsurface vacuum and soil vapor concentrations are monitored with vadose zone monitoring wells.

The technology is effective in most hydrogeological settings, and can reduce soil contaminant levels from saturated conditions to nondetectable. The process even works in less permeable soils (clays) with sufficient porosity. Dual vacuum extraction of groundwater and vapor quickly restores groundwater quality to drinking water standards. In addition, the technology is less expensive than other remediation methods, such as incineration. The figure below illustrates the process.

Typical contaminant recovery rates range from 20 to 2,500 pounds per day, depending on the degree of site contamination.

WASTE APPLICABILITY:

The vacuum extraction technology effectively treats soils containing virtually any VOC and has



In Situ Vacuum Extraction Process

The SITE Program assesses but does not approve or endorse technologies.

successfully removed over 40 types of chemicals from soils and groundwater, including solvents and gasoline- and diesel-range hydrocarbons.

STATUS:

The vacuum extraction process was first demonstrated at a Superfund site in Puerto Rico. Terra Vac has since applied the technology at fifteen additional Superfund sites and at more than 400 other waste sites throughout the United States, Europe, and Japan.

The process was demonstrated under the SITE Demonstration Program at the Groveland Wells Superfund site in Groveland, Massachusetts, from December 1987 through April 1988. The technology successfully remediated soils contaminated by trichloroethene (TCE). The Technology Evaluation Report (EPA/540/5-89/003a) and Applications Analysis Report (EPA/540/A5-89/003) have been published.

DEMONSTRATION RESULTS:

During the Groveland Wells demonstration, four extraction wells pumped contaminants to the process system. During a 56-day operational period, 1,300 pounds of VOCs, mainly TCE, were extracted from both highly permeable strata and less permeable clays. The vacuum extraction process achieved nondetectable VOC levels at some locations, and reduced the VOC concentration in soil gas by 95 percent. Average reductions were 92 percent for sandy soils and 90 percent for clays. Field evaluations have yielded the following conclusions:

- VOCs can be reduced to nondetectable levels; however, some residual VOC concentrations usually remained in the treated soils.
- Volatility of the contaminants and site soils is a major consideration when applying this technology. Ideal measured permeabilities are 10^{-4} to 10^{-8} centimeters per second.
- Pilot demonstrations are necessary at sites with complex geology or contaminant distributions.
- Treatment costs are typically $40 per ton of soil, but can range from $10 to $150 per ton of soil, depending on requirements for gas effluent or wastewater treatment.
- Contaminants should have a Henry's constant of 0.001 or higher.

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The SITE Program assesses but does not approve or endorse technologies.

TEXACO INC.
(Entrained-Bed Gasification)

TECHNOLOGY DESCRIPTION:

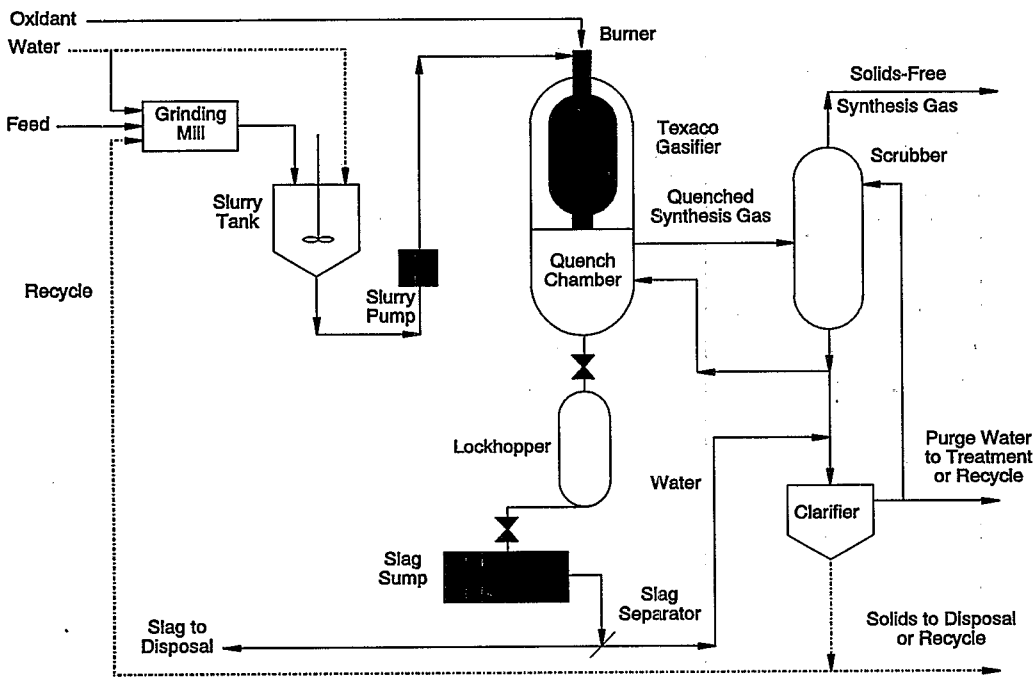
The Texaco entrained-bed gasification process is a noncatalytic, partial oxidation process in which carbonaceous substances react at elevated temperatures and pressures, producing a gas containing mainly carbon monoxide and hydrogen (see figure below). This product, called synthesis gas, can be used to produce other chemicals or burned as fuel. Feed ash melts and is removed as a glass-like slag. Applying this technology to the treatment of hazardous waste is an extension of Texaco's conventional gasification technology, which has operated commercially for over 40 years with feedstocks such as natural gas, heavy oil, coal, and petroleum coke.

The Texaco gasification process (TGP) treats waste material at pressures above 20 atmospheres and temperatures between 2,200 and 2,800 degrees Fahrenheit.

Slurried wastes are pumped to a specially designed burner mounted at the top of a refractory-lined pressure vessel. The waste feed, containing oxygen and an auxiliary fuel such as coal, reacts and flows downward through the gasifier to a quench chamber that collects the slag. The slag is eventually removed through a lockhopper. A scrubber further cools and cleans the synthesis gas. Fine particulate matter removed by the scrubber may be recycled to the gasifier; a sulfur recovery system may also be added.

After the TGP converts organic materials into synthesis gas, the cooled, water-scrubbed product gas, consisting mainly of hydrogen and carbon monoxide, should contain no hydrocarbons heavier than methane. Metals and other ash constituents become part of the glassy slag.

Texaco is designing a transportable system to treat about 100 tons of hazardous waste per day.



Entrained-Bed Gasification Process

The SITE Program assesses but does not approve or endorse technologies.

This system would produce about 6 million standard cubic feet of usable synthesis gas per day with a heat content of 250 British thermal units per standard cubic foot.

WASTE APPLICABILITY:

Examples of wastes that the gasification system can treat are:

- contaminated soils, sludges, and sediments that contain both organic and inorganic constituents
- chemical wastes
- petroleum residues

Solids in the feed must be ground and pumped in a slurry containing 40 to 70 percent solids by weight and 30 to 60 percent liquid, usually water.

Texaco has demonstrated gasification of coal liquefaction residues, petroleum production tank bottoms, municipal sewage sludge, and surrogate contaminated soil. Texaco plans to build a gasification power facility at its El Dorado, Kansas refinery that will convert about 170 tons of noncommercial petroleum coke and refinery wastes per day into clean synthesis gas.

STATUS:

The gasification system was accepted into the SITE Demonstration Program in July 1991. A demonstration was conducted in January 1994 at Texaco's Montebello Research Laboratory using a mixture of clean soil, coal, and soil from the Purity Oil Sales Superfund Site, located in Fresno, California. The mixture was slurried and spiked with lead, barium, and chlorobenzene. Forty tons of slurry were treated in preparation for and during three demonstration runs. Detailed demonstration results will be published in late 1994.

DEMONSTRATION RESULTS:

Preliminary findings from the demonstration are summarized below:

- The average composition of the dry synthesis gas product from the TGP consisted of 37 percent hydrogen, 36 percent carbon monoxide, and 21 percent carbon dioxide. The only remaining organic contaminant greater than 0.1 parts per million (ppm) was methane at 55 ppm.
- The destruction and removal efficiency for the volatile organic spike (chlorobenzene) was greater than the 99.99-percent goal.
- Samples of the primary TGP solid product, coarse slag, averaged below the toxicity characteristic leaching procedure (TCLP) regulatory values for lead (5 milligrams per liter [mg/L]) and barium (100 mg/L). Volatile heavy metals tended to partition to and concentrate in the secondary TGP solid products, fine slag and clarifier solids. These secondary products were above the TCLP regulatory value for lead.

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The SITE Program assesses but does not approve or endorse technologies.

TORONTO HARBOUR COMMISSION
(Soil Recycling)

TECHNOLOGY DESCRIPTION:

The Toronto Harbour Commission's soil recycling process removes inorganic and organic contaminants from soil to produce a reusable fill material. The process involves three technologies operating in series.

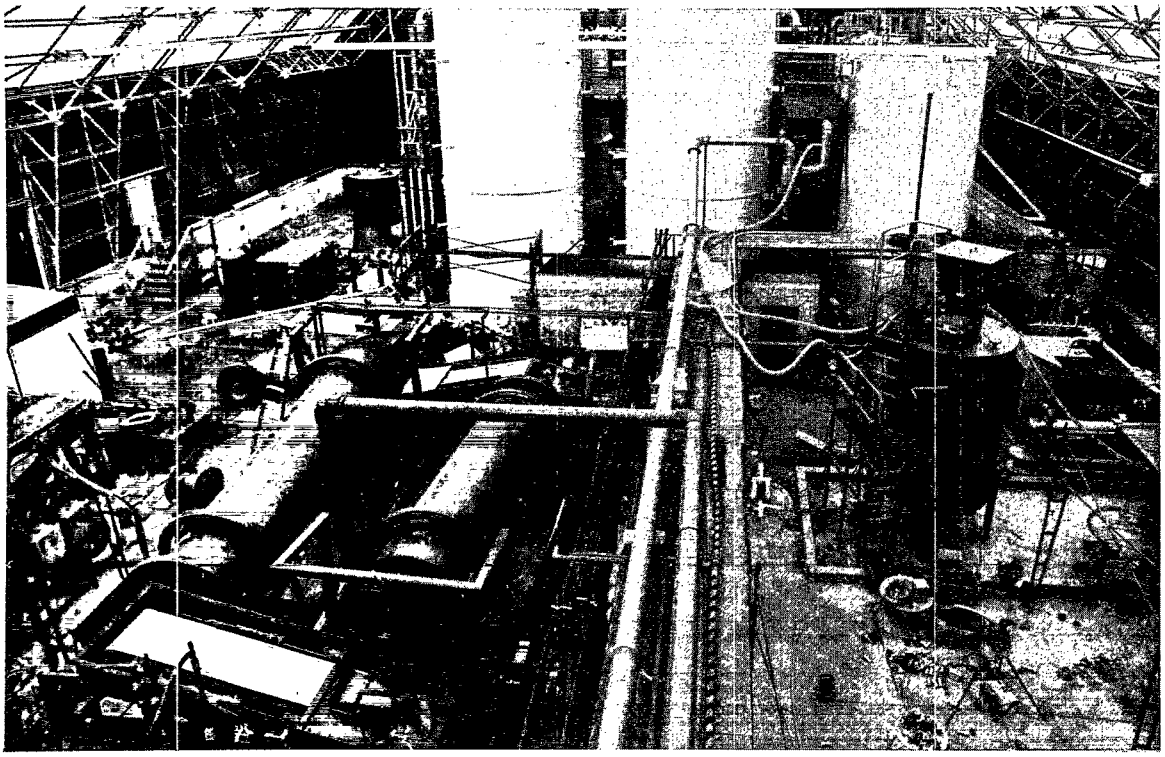
The first technology is a soil washing process that reduces the volume of treatable material by concentrating contaminants in a fine slurry mixture. The second technology removes heavy metals from the slurry by dissolving the metals with acid and selective chelation. The metal dissolution process recovers all metals in their pure forms. The third technology, chemical hydrolysis accompanied by bioslurry reactors, destroys organic contaminants concentrated in the slurry. The three integrated technologies are capable of cleaning contaminated soil for reuse on industrial sites.

WASTE APPLICABILITY:

This technology is applicable to soil contaminated with inorganics and organics.

STATUS:

Toronto Harbour Commission's soil recycling process was accepted into the SITE Demonstration Program in 1991. The soil recycling process was demonstrated at a site within the Toronto Port Industrial District that had been used for metals finishing and refinery products and petroleum storage. Demonstration sampling took place in April and May 1992.



Soil Washing Plant (Metal Extraction Screwtubes in Foreground and Bioslurry Reactors in Background)

The SITE Program assesses but does not approve or endorse technologies.

The objective of the SITE demonstration was to evaluate the process' ability to achieve the modified Ontario Ministry of the Environment (MOE) criteria for commercial and industrial sites. Detailed results have been published in a Demonstration Bulletin (EPA/520-MR-92/015), an Applications Analysis Report (EPA/540-AR-93/517), a Technology Evaluation Report (EPA/540/R-93/517), and a Technology Demonstration Summary (EPA/540/SR-93/517). These reports are available from EPA.

DEMONSTRATION RESULTS:

The demonstration results showed that soil washing effectively produced clean coarse soil fractions and concentrated the contaminants in the fine slurry (see Table 1).

Table 1 - Soil Washing Process

	Feed	Clean Sand	Contaminated Fine Slurry
Oil & Grease	.8 mg/kg*	.2 mg/kg	4 mg/kg
Naphthalene	11 mg/kg	2 mg/kg	52 mg/kg
Benzo(a)pyrene	2 mg/kg	.5 mg/kg	10 mg/kg

* milligrams per kilogram

The heavy metals process effectively treated samples of contaminated soil from the Port Industrial Area, lead-contaminated soil from a lead smelter site, contaminated harbour sediments, municipal sewage sludge, and municipal sewage incinerator ash (see Table 2).

Table 2 - Heavy Metals Process

Metal	Lead Smelter Soil Fines Input	Treated Fines Output
Sample #1623 - Lead	2949 mg/kg	877 mg/kg
Sample #1631 - Lead	612 mg/kg	183 mg/kg

The heavy metals process has been licensed to Metanetix Corporation for worldwide application. It is being applied commercially to selective mine metals from acid mine drainage at the Anaconda copper mine in Butte, Montana. The chemical treatment process and bioslurry reactors achieved a 90 percent reduction in polynuclear aromatic hydrocarbon compounds such as naphthalene, but slightly exceeded the MOE criteria for benzo(a)pyrene (see Table 3).

Table 3 - Chemical and Bioremediation Process

	Contaminated Fine Slurry	Treated Fine Slurry
Naphthalene	52 mg/kg	<5 mg/kg
Benzo(a)pyrene	10 mg/kg	2.6 mg/kg

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The SITE Program assesses but does not approve or endorse technologies.

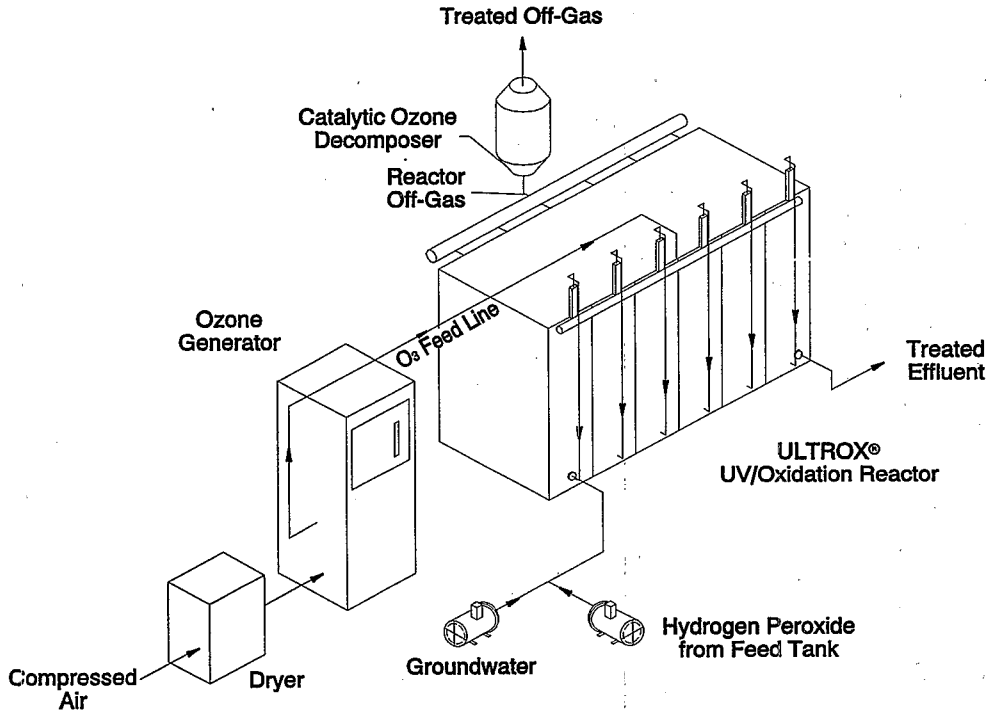
ULTROX, A DIVISION OF ZIMPRO ENVIRONMENTAL, INC.
(Ultraviolet Radiation and Oxidation)

TECHNOLOGY DESCRIPTION:

This ultraviolet (UV) radiation and oxidation process uses UV radiation, ozone (O_3), and hydrogen peroxide (H_2O_2) to destroy toxic organic compounds, particularly chlorinated hydrocarbons, in water. The process oxidizes compounds that are toxic or refractory (resistant to biological oxidation) to parts per million (ppm) or parts per billion (ppb) levels.

The UV radiation and oxidation system consists of a treatment tank module, an air compressor and ozone generator module, and a hydrogen peroxide feed system (see figure below). The system is skid-mounted and portable, and permits on-site treatment of a wide variety of liquid wastes, such as industrial wastewater, groundwater, and leachate. Treatment tank size is determined by the expected wastewater flow rate and the necessary hydraulic retention time needed to treat the contaminated water. The approximate UV intensity, and ozone and hydrogen peroxide doses, are determined by pilot-scale studies.

Treatment tank influent is simultaneously exposed to UV radiation, ozone, and hydrogen peroxide to oxidize the organic compounds. Off-gas from the treatment tank passes through an ozone destruction Decompozon™ unit, which reduces ozone levels before air venting. The Decompozon™ unit also destroys volatile organic compounds (VOC) stripped off in the treatment tank. Effluent from the treatment tank is tested and analyzed before disposal.



Ultrox System (Isometric View)

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The UV radiation and oxidation system treats contaminated groundwater, industrial wastewaters, and leachates containing halogenated solvents, phenol, pentachlorophenol, pesticides, polychlorinated biphenyls, explosives, benzene, toluene, ethylbenzene, xylene, methyl tertiary butyl ether, and other organic compounds. The system also treats low level total organic compounds, chemical oxygen demand, and biological oxygen demand.

STATUS:

A field-scale demonstration was completed in March 1989 at the Lorentz Barrel and Drum Company site in San Jose, California. The test program was designed to evaluate system performance for several combinations of five operating parameters: 1) influent pH, 2) retention time, 3) ozone dose, 4) hydrogen peroxide dose, and 5) UV radiation intensity. The Technology Evaluation Report was published in January 1990 (EPA/540/5-89/012). The Applications Analysis Report was published in September 1990 (EPA/540/A5-89/012).

The technology is fully commercial, with over 30 systems installed. Flow rates ranging from 5 gallons per minute (gpm) to 1,050 gpm are in use at various industries and site remediations, including aerospace, U.S. Department of Energy, U.S. Department of Defense, petroleum, pharmaceutical, automotive, woodtreating, and municipal facilities.

UV oxidation technology has been included in Records of Decision for several Superfund sites where groundwater pump-and-treat remediation methods will be used.

DEMONSTRATION RESULTS:

Contaminated groundwater treated by the system met regulatory standards at the appropriate parameter levels. Out of 44 VOCs in the wastewater, trichloroethene, 1,1-dichloroethane, and 1,1,1-trichloroethane were chosen as indicator parameters. All three are relatively refractory to conventional oxidation.

The Decompozon™ unit reduced ozone to less than 0.1 ppm, with efficiencies greater then 99.99 percent. VOCs present in the air within the treatment system were not detected after passing through the Decompozon™ unit. The Ultrox system produced no harmful air emissions. Total organic carbon removal was low, implying partial oxidation of organics without complete conversion to carbon dioxide and water.

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The SITE Program assesses but does not approve or endorse technologies.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
(Excavation Techniques and Foam Suppression Methods)

TECHNOLOGY DESCRIPTION:

These excavation techniques and foam suppression methods were developed through a joint EPA effort involving the Risk Reduction Engineering Laboratory (Cincinnati, Ohio), Air and Energy Engineering Research Laboratory (Research Triangle Park, North Carolina), and EPA Region 9 to evaluate control technologies during excavation operations.

In general, excavating soil contaminated with volatile organic compounds (VOC) results in fugitive air emissions. The area to be excavated is surrounded by a temporary enclosure (see photograph below). Air from the enclosure is vented through an emission control system before being released to the atmosphere. For example, in the case of hydrocarbon and sulfur dioxide emissions, a scrubber and a carbon adsorption unit would be used to treat emissions. As an additional emission control method, a vapor suppressant foam can be applied to the soil before and after excavation.

WASTE APPLICABILITY:

This technology is suitable for controlling VOC emissions during excavation of contaminated soil.

STATUS:

This technology was demonstrated at the McColl Superfund site in Fullerton, California, in June and July 1990. An enclosure 60 feet wide, 160 feet long, and 26 feet high was erected over an area contaminated with VOCs and sulfur

Excavation Area Enclosure

The SITE Program assesses but does not approve or endorse technologies.

dioxide. A backhoe removed the overburden and excavated underlying waste. Three distinct types of waste were encountered during excavation: oily mud, tar, and hard coal-like char.

The following documents contain results of the demonstration and are available from EPA:

- Applications Analysis Report (EPA/540/AR-92/015)
- Technology Evaluation Report (EPA/540/R-93/015)
- Demonstration Summary (EPA/540/SR-92/015)

DEMONSTRATION RESULTS:

During excavation, the 5-minute average air concentrations within the enclosed area were up to 1,000 parts per million (ppm) for sulfur dioxide and up to 492 ppm for total hydrocarbons (THC). The air pollution control system removed up to 99 percent of the sulfur dioxide and up to 70 percent of the THCs.

The concentrations of air contaminants inside the enclosure were higher than expected. These high concentrations were due in part to the vapor suppressant foams' inability to form an impermeable membrane over the exposed wastes. The foam reacted with the highly acidic waste, causing the foam to degrade. Furthermore, purge water from foaming activities made surfaces slippery for workers and equipment.

A total of 101 cubic yards of overburden and 137 cubic yards of contaminated waste was excavated. The tar waste was solidified and stabilized by mixing it with fly ash, cement, and water in a pug mill. The char wastes did not require further processing.

FOR FURTHER INFORMATION:

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San Francisco, CA 94105
415-744-2400

The SITE Program assesses but does not approve or endorse technologies.

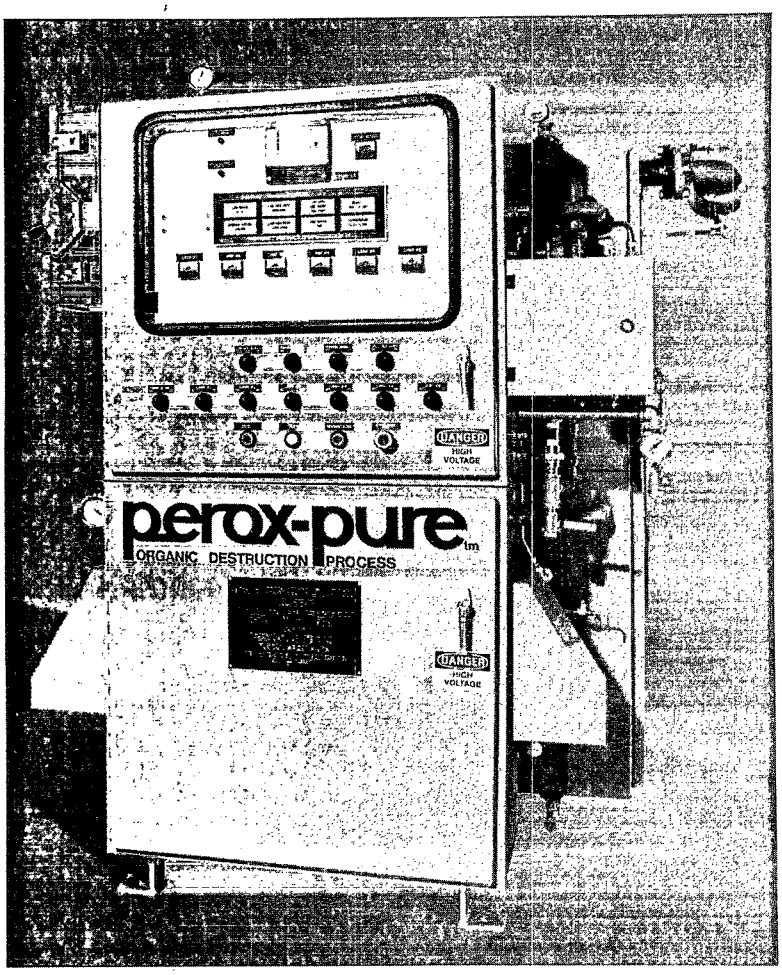
VULCAN PEROXIDATION SYSTEMS, INC.
(formerly PEROXIDATION SYSTEMS, INC.)
(perox-pure™ Chemical Oxidation Technology)

TECHNOLOGY DESCRIPTION:

The **perox-pure™** treatment system is designed to destroy dissolved organic contaminants in groundwater or wastewater with an advanced chemical oxidation process that uses ultraviolet (UV) radiation and hydrogen peroxide. Hydrogen peroxide is added to the contaminated water, and the mixture is then fed into the treatment system.

The treatment system's oxidation chamber contains one or more compartments. Each compartment contains one high-intensity UV lamp mounted in a quartz tube. The contaminated water flows in the space between the chamber wall and the quartz tube in which each UV lamp is mounted. The **perox-pure™** equipment includes circular wipers attached to the quartz tubes. These wipers periodically remove solids that may accumulate on the tubes, a feature designed to maintain treatment efficiency.

UV light catalyzes chemical oxidation of organic contaminants in water by affecting the organics and reacting with hydrogen peroxide. Many



perox-pure™ Model SSB-30

The SITE Program assesses but does not approve or endorse technologies.

organic contaminants that absorb UV light change chemically or become more reactive with chemical oxidants. More importantly, UV light catalyzes hydrogen peroxide breakdown to produce hydroxyl radicals, which are powerful chemical oxidants. Hydroxyl radicals react with and destroy organic contaminants, ultimately producing harmless by-products such as carbon dioxide, halides, and water. The treatment system produces no hazardous by-products or air emissions.

WASTE APPLICABILITY:

The **perox-pure™** technology treats groundwater and wastewater contaminated with chlorinated solvents, pesticides, polychlorinated biphenyls, phenolics, fuel hydrocarbons, and other organic compounds at concentrations ranging from a few thousand milligrams per liter to one microgram per liter or lower. In some cases, the treatment system can combine with air stripping, steam stripping, or biological treatment to optimize treatment results.

STATUS:

The **perox-pure™** technology was accepted into the SITE Demonstration Program in April 1991. A Model SSB-30 was demonstrated in September 1992 at the Lawrence Livermore National Laboratory Site 300 Superfund site in California. The purpose of this demonstration was to measure how well the **perox-pure™** technology removed volatile organic compounds (VOC) from contaminated groundwater at the site.

This technology has been successfully applied to over 80 sites throughout the United States, Canada, and Europe. The treatment units at these sites have treated contaminated groundwater, industrial wastewater, landfill leachates, potable water, and industrial reuse streams. Equipment capacities range up to several thousand gallons per minute.

DEMONSTRATION RESULTS:

During the demonstration, the treatment system operated at a variety of operating parameters. Three reproducibility tests were performed at the optimum operating conditions, which were selected from the initial test runs.

In most cases, the **perox-pure™** technology reduced trichloroethene, tetrachloroethene, chloroform, trichloroethane, and dichloroethane to below analytical detection limits. For each organic contaminant, the **perox-pure™** technology complied with California action levels and federal drinking water maximum contaminant levels at the 95 percent confidence level. The quartz tube wipers effectively cleaned the tubes and eliminated the interference caused by tube scaling. The Applications Analysis Report (EPA/540/AR-93/501), the Technology Evaluation Report (EPA/540/R-93/501) and the Technology Demonstration Summary (EPA/540/SR-93/501) are available from EPA.

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The SITE Program assesses but does not approve or endorse technologies.

WASTECH, INC.
(Solidification and Stabilization)

TECHNOLOGY DESCRIPTION:

This solidification and stabilization technology applies proprietary bonding agents to soils, sludge, and liquid wastes contaminated with organic and inorganic contaminants. The technology uses a reagent to chemically bond with contaminants in wastes. The waste and reagent mixture is then mixed with pozzolanic, cementitious materials, which combine to form a stabilized matrix. Reagents are selected based on target waste characteristics. Treated material is a nonleaching, high-strength, stabilized end-product.

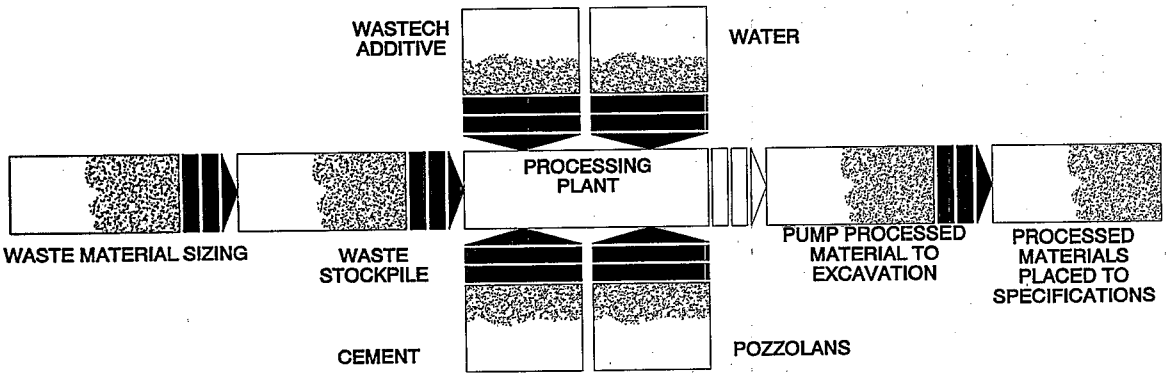
WASTECH, Inc.'s (WASTECH), technology uses standard engineering and construction equipment. As the type and dose of reagents depend on waste characteristics, treatability studies and site investigations must be conducted to determine the proper treatment formula.

Treatment usually begins with waste excavation. Large pieces of debris in the waste must be screened and removed. The waste is then placed into a high shear mixer, along with premeasured quantities of water and SuperSet®, WASTECH's proprietary reagent (see figure below).

Next, pozzolanic, cementitious materials are added to the waste-reagent mixture, stabilizing the waste and completing the treatment process. WASTECH's treatment technology does not generate by-products. The process may also be applied in situ.

WASTE APPLICABILITY:

WASTECH's technology can treat a wide variety of waste streams consisting of soils, sludges, and raw organic streams, including lubricating oil, aromatic solvents, evaporator bottoms, chelating agents, and ion exchange resins, with contaminant concentrations ranging from parts per million levels to 40 percent by volume. The technology can also treat wastes generated by the petroleum, chemical, pesticide, and wood-preserving industries, as well as wastes generated by many other chemical manufacturing and industrial processes. WASTECH's technology



WASTECH Solidification and Stabilization Process

The SITE Program assesses but does not approve or endorse technologies.

can also be applied to mixed wastes containing organic, inorganic, and radioactive contaminants.

STATUS:

The technology was accepted into the SITE Demonstration Program in spring 1989. A field demonstration at Robins Air Force Base in Warner Robins, Georgia was completed in August 1991. The WASTECH technology treated high level organic and inorganic wastes at an industrial sludge pit. WASTECH subsequently conducted a bench-scale study under glovebox conditions to develop a detailed mass balance of volatile organic compounds in late 1992. The technology is being commercially applied to treat hazardous wastes contaminated with various organics, inorganics, and mixed wastes. The Innovative Technology Evaluation Report will be available in 1995.

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The SITE Program assesses but does not approve or endorse technologies.

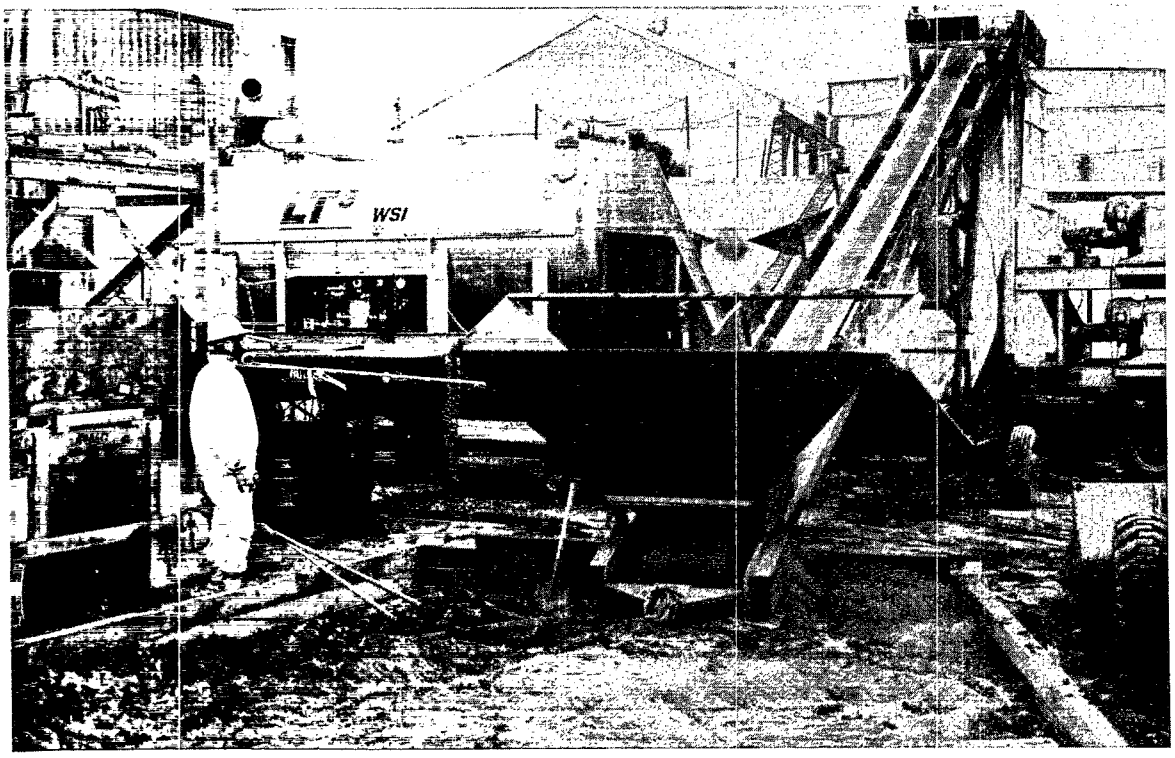
ROY F. WESTON, INC.
(Low Temperature Thermal Treatment [LT³®] System)

TECHNOLOGY DESCRIPTION:

The Roy F. Weston, Inc. (Weston), low temperature thermal treatment (LT³®) system thermally desorbs organic compounds from contaminated soil without heating the soil to combustion temperatures. The transportable system is assembled on three flat-bed trailers and requires an area of about 5,000 square feet, including ancillary and support equipment. The LT³® system consists of three segments: soil treatment, emissions control, and water treatment (see figure below).

The LT³® thermal processor consists of two jacketed troughs, one above the other. Each trough houses four intermeshed, hollow screw conveyors. A front-end loader feeds soil or sludge onto a conveyor that discharges into a surge hopper above the thermal processor. Hot oil circulating through the troughs and screws heats the soil to 400 to 500 degrees Fahrenheit, removing contaminants. Soil is discharged from the thermal processor into a conditioner where a water spray cools the soil and minimizes dust emissions.

A fan draws desorbed organics from the thermal processor through a fabric filter baghouse. Depending on contaminant characteristics, dust collected on the fabric filter may be retreated, combined with treated material, or drummed separately for off-site disposal. Exhaust gas from the fabric filter is drawn into an air-cooled condenser to remove most of the water vapor and organics. The gas is then passed through a second, refrigerated condenser and treated by carbon adsorption.



Low Temperature Thermal Treatment System

The SITE Program assesses but does not approve or endorse technologies.

Condensate streams are typically treated in a three-phase oil-water separator to remove light and heavy organic phases from the water phase, which is then treated in the carbon adsorption system to remove residual organic contaminants. Treated condensate is often used for soil conditioning, and only the organic phases are disposed of off site.

WASTE APPLICABILITY:

This system treats soils contaminated with volatile and semivolatile organic compounds (VOC and SVOC). Bench-, pilot-, and full-scale LT³® systems have treated soil contaminated with the following wastes: coal tar, drill cuttings (oil-based mud), No. 2 diesel fuel, JP-4 jet fuel, leaded and unleaded gasoline, petroleum hydrocarbons, halogenated and nonhalogenated solvents, VOCs, SVOCs, and polynuclear aromatic hydrocarbons.

STATUS:

The LT³® system was accepted into the SITE Demonstration Program in September 1991. In November and December 1991, the LT³® system was demonstrated under the SITE Program as part of a proof-of-process test for full-scale remediation of the Anderson Development Company (ADC) Superfund site in Adrian, Michigan. The system was tested on lagoon sludge from the ADC site. This sludge was contaminated with VOCs and SVOCs, including 4,4-methylene bis(2-chloroaniline) (MBOCA).

DEMONSTRATION RESULTS:

The SITE demonstration yielded the following results:

- The LT³® system removed VOCs to below method detection limits (less than 0.060 milligrams per kilogram [mg/kg] for most compounds).
- The LT³® system achieved MBOCA removal efficiencies greater than 88 percent; MBOCA concentrations in the treated sludge ranged from 3.0 to 9.6 mg/kg.
- The LT³® system decreased the concentrations of all SVOCs in the sludge, with the exception of phenol, which increased as a result of the chlorobenzene decrease.
- Stack emissions of non-methane total hydrocarbons increased from 6.7 to 11 parts per million by volume during the demonstration; the maximum emission rate was 0.2 pounds per day (ppd). The maximum particulates emission rate was 0.02 ppd, and no chlorides were measured in stack gases.

The Demonstration Bulletin (EPA/540/MR-92/019) and Applications Analysis Report (EPA/540/AR-92/019) are available from EPA. The Technology Evaluation Report will be available in late 1994.

FOR FURTHER INFORMATION:

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The SITE Program assesses but does not approve or endorse technologies.

ROY F. WESTON, INC./IEG TECHNOLOGIES
(UVB - Vacuum Vaporizing Well)

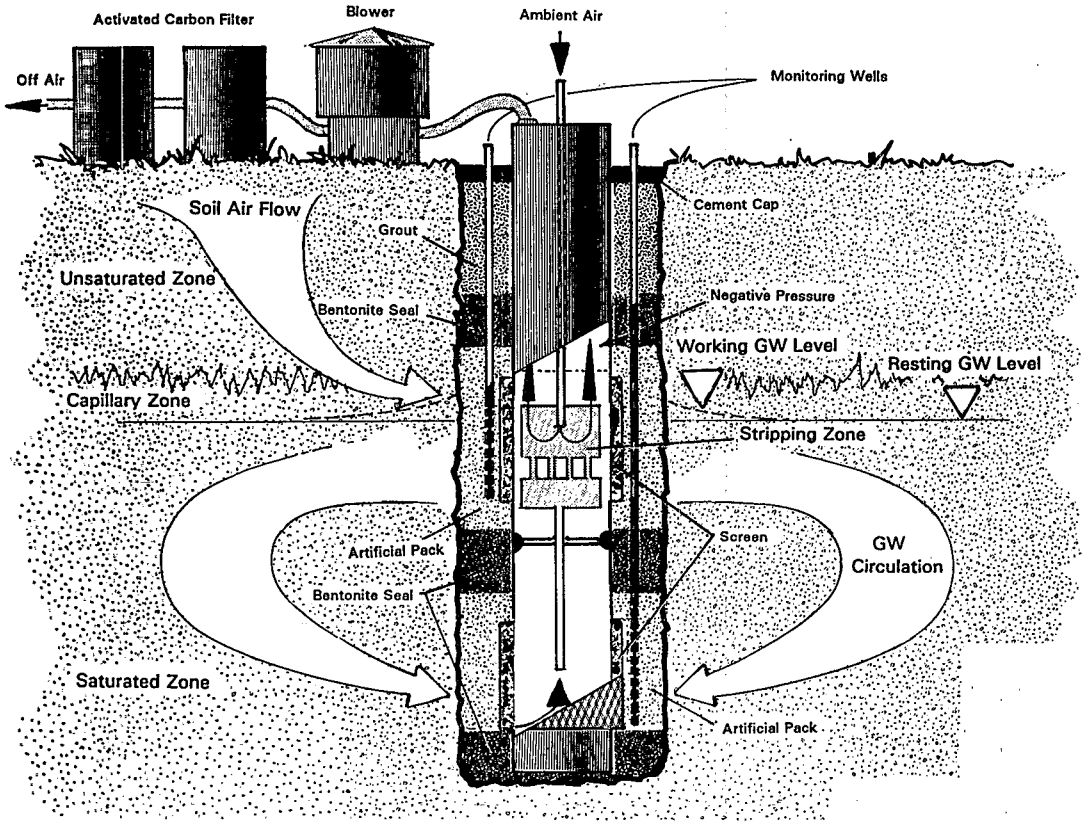
TECHNOLOGY DESCRIPTION:

The Unterdruck-Verdampfer Brunnen (UVB) vacuum vaporizing well is an in situ system for remediating contaminated aquifers, especially those contaminated with volatile organic compounds. The UVB system uses a combination of chemical, physical and biological processes.

A UVB system consists of a specially adapted groundwater well, a negative pressure stripping reactor, an aboveground mounted blower, and a waste air decontamination system such as disposable activated carbon beds (see figure below).

The water level rises about 1 foot inside the well due to negative pressure generated by a blower. Fresh air is drawn into the system through a pipe leading to the stripping reactor and passes up through the raised water. The rising air bubbles enhance the suction effect at the bottom of the well, creating an air-lift pump. A specific flow direction can be induced by adding a support pump to produce an up or down vertical flow either upward or downward within the well.

As a result of the concentration gradient, the contaminants vaporize into the air bubbles and are removed from the well by the air flow. The oscillating hydraulic pressure forces the water horizontally into the aquifer through the top screened well segment. In the surrounding aquifer, a circulation system develops, water enters at the well base and leaves through the upper screened segment, or vice versa, depending on the desired flow direction.



UVB Standard Circulation

The SITE Program assesses but does not approve or endorse technologies.

A flow pattern with a calculable horizontal and vertical component is produced in the aquifer to compensate for the directed water flow within the UVB well. Thus, treated groundwater circulates through the sphere of influence within the aquifer before returning to the well.

The UVB technology can extract soil gas during groundwater treatment. The amount of soil gas and groundwater passing through the decontamination system can be adjusted according to the type of contamination and the well construction.

WASTE APPLICABILITY:

The UVB technology is designed to remove volatile organic compounds from groundwater. Depending on the circumstances, the UVB system may also remediate semivolatile compounds and heavy metals.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1993. The 6-month demonstration at March Air Force Base, California was extended for one year, and was completed in May 1994.

DEMONSTRATION RESULTS:

Demonstration results indicate that trichloroethene (TCE) was reduced on average by greater than 94 percent in groundwater discharged from the UVB treatment system. The mean TCE concentration in the discharged groundwater was approximately 3 micrograms per liter (μg/L), with only one event above 5 μg/L. The UVB system's ability to remove dichloroethene (DCE) could not be established due to the low (less than 4 μg/L) influent concentration of DCE.

Based on the dye-tracer study, the radius of influence was measured to be at least 40 feet. Modeling of the radius of influence by Roy F. Weston, Inc., suggests that it may extend to a distance of approximately 83 feet; however, site-specific data obtained from aquifer testing indicate that the radius of influence is probably between 60 and 80 feet.

In general, TCE and DCE in the shallow and intermediate screen wells showed a concentration reduction both vertically and horizontally over the duration of the pilot study. Target compound concentrations in these zones appeared to homogenize as indicated by the convergence and stabilization of TCE and DCE concentrations. Variations in target compound concentrations were noted in the deep screened wells; however, there was no evidence of reduction or homogenization of the TCE or DCE in these wells. This may be due to the limited duration of well monitoring.

FOR FURTHER INFORMATION:

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The SITE Program assesses but does not approve or endorse technologies.

WHEELABRATOR CLEAN AIR SYSTEMS, INC.
(formerly CHEMICAL WASTE MANAGEMENT, INC.)
(PO*WW*ER™ Technology)

TECHNOLOGY DESCRIPTION:

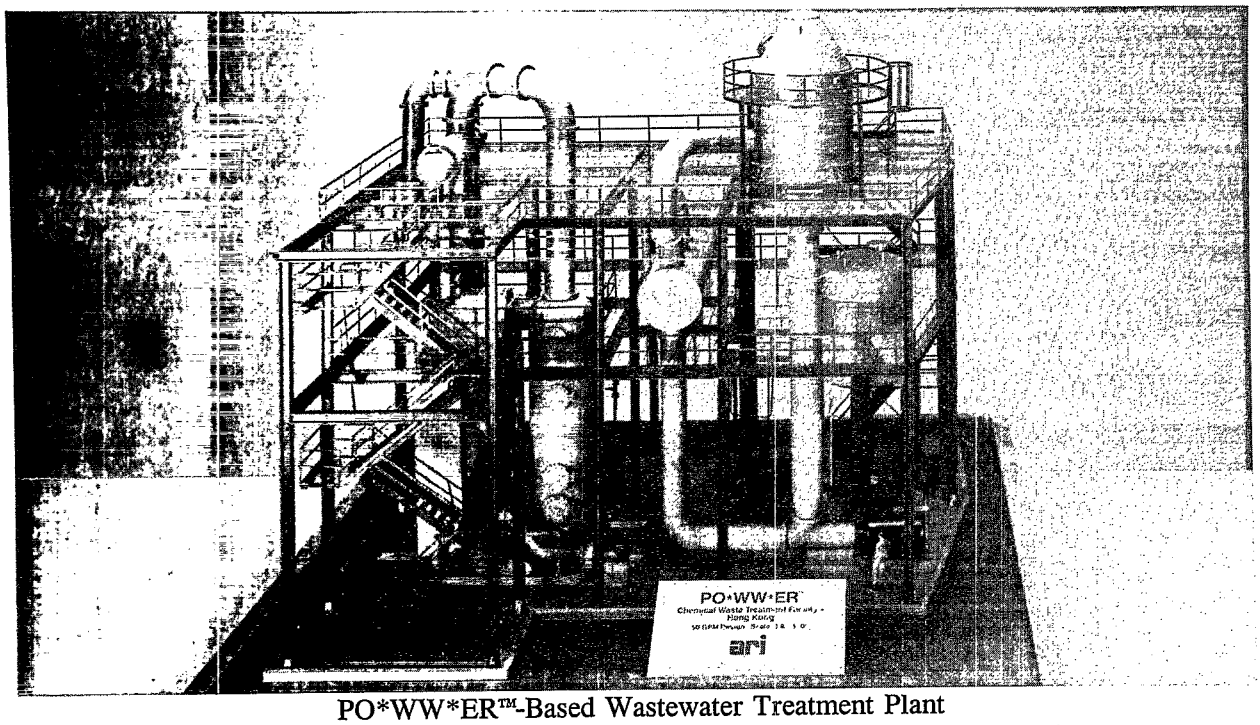
The PO*WW*ER™ technology is used to treat and reduce complex industrial and hazardous wastewaters containing mixtures of inorganic salts, metals, volatile and nonvolatile organics, volatile inorganics, and radionuclides. The proprietary technology combines evaporation with catalytic oxidation to concentrate and destroy contaminants, producing a high-quality product condensate.

Wastewater is first pumped into an evaporator where most of the water and contaminants are vaporized and removed, concentrating the contaminants into a small volume for further treatment or disposal. The contaminant vapors then pass over a bed of proprietary robust catalyst, where the pollutants are oxidized and destroyed. Depending upon the composition, effluent vapors from the oxidizer may be treated in a scrubber. The vapors are then condensed to produce water (condensate) that can be used as either boiler or cooling tower make-up water, if appropriate. Hazardous wastewater is thus separated into a small contaminant stream and a large clean water stream without using expensive reagents or increasing the volume of the total stream. The photograph below illustrates a PO*WW*ER™-based wastewater treatment plant.

WASTE APPLICABILITY:

The PO*WW*ER™ technology can treat wastewaters containing a mixture of the following contaminants:

Organic	Inorganic	Radioactive
• Halogenated volatiles • Halogenated semivolatiles • Nonhalogenated volatiles • Nonhalogenated semi-volatiles • Organic pesticides/ herbicides • Solvents • Benzene, toluene, ethyl-benzene, and xylene • Organic cyanides • Nonvolatile organics	• Heavy metals • Nonmetallic toxic elements • Cyanides • Ammonia • Nitrates • Salts	• Plutonium • Americium • Uranium • Technetium • Thorium • Radium • Barium



PO*WW*ER™-Based Wastewater Treatment Plant

The SITE Program assesses but does not approve or endorse technologies.

Suitable wastewaters include landfill leachates, contaminated groundwaters, process wastewaters, and low-level radioactive mixed wastes.

STATUS:

The technology was accepted into the SITE Demonstration Program in 1991, and was tested on landfill leachate in September 1992 at the developer's pilot plant in Lake Charles, Louisiana (see photograph below). The Applications Analysis Report (EPA/540/AR-93/506) and the Technology Evaluation Report (EPA/540/R93/506) are available from EPA.

A commercial system (50 gallons per minute capacity) is in operation at Ysing Yi Island, Hong Kong. A pilot-scale unit (1 to 1.5 gallons per hour) is available at RUST Remedial Services' Clemson Technical Center in South Carolina and can treat both radioactive, hazardous, and mixed waste streams.

FOR FURTHER INFORMATION:

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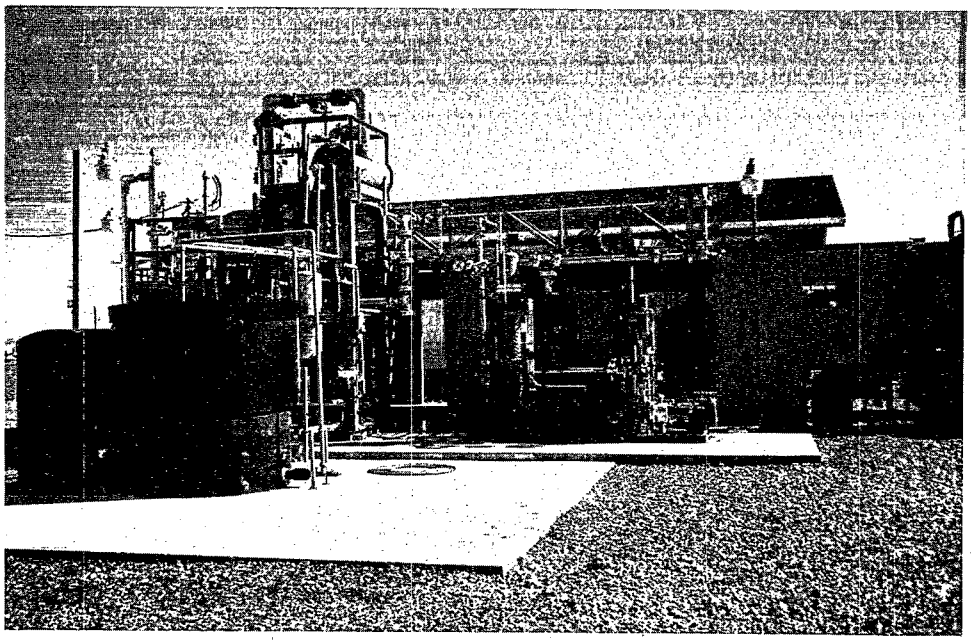


PO*WW*ER™ Pilot Plant at Chemical Waste Management's Lake Charles, Louisiana Facility

The SITE Program assesses but does not approve or endorse technologies.

TABLE 2

Ongoing SITE Demonstration Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Accutech Remedial Systems, Inc.,* Keyport, NJ (005)**	Pneumatic Fracturing Extraction℠ and Catalytic Oxidation	John Liskowitz 908-739-6444	Uwe Frank 908-321-6626	Soil, Rock	Not Applicable	Halogenated and Nonhalogenated VOCs and SVOCs
AlliedSignal Environmental Systems and Services, Des Plaines, IL (003)	Immobilized Cell Bioreactor Biotreatment System	F. Stephen Lupton 708-391-3224 Conrad Kempton 201-455-5531	Ronald Lewis 513-569-7856	Groundwater, Wastewater	Not Applicable	Readily Biodegradable Organic Compounds, PAHs, Diesel Fuel, Chlorobenzene
Andco Environmental Processes, Inc., Buffalo, NY (007)	Electrochemical In Situ Chromate Reduction and Heavy Metal Immobilization	Michael Laschinger 716-691-2100	Douglas Grosse 513-569-7844	Groundwater	Heavy Metals, Hexavalent Chromium	Not Applicable
Aprotek, Sacramento, CA (008)	Ion Conduction Agglomeration System	Cathryn Wimberly 916-366-6165	Jack Hubbard 513-569-7507	Groundwater, Wastewaster, Mining Effluents	Metals	Not Applicable
ASI Environmental Technologies, Inc./ Dames & Moore, Brandon, FL (005)	Hydrolytic Terrestrial Dissipation	Stoddard Pickrell 813-653-3376	Ronald Lewis 513-569-7856	Soil	Not Applicable	Toxaphene and Other Pesticides
BioGenesis Enterprises, Inc.,* Springfield, VA (009)	BioGenesis℠ Soil and Sediment Washing Process	Thomas Rougeux 703-913-9700	Annette Gatchett 513-569-7697	Soil	Not Applicable	Volatile and Nonvolatile Hydrocarbons, PCBs
CF Systems Corporation,* Woburn, MA (008)	Liquified Gas Solvent Extraction (LG-SX) Technology	Chris Shallice 617-937-0800	Mark Meckes 513-569-7348	Soil, Sludge, Wastewater	Not Applicable	VOCs, SVOCs, PAHs, PCBs, Dioxins, Pentachlorophenol
Colorado Department of Public Health and Environment (developed by Colorado School of Mines),*** Denver, CO (005)/(E01)	Wetlands-Based Treatment	Rick Brown 303-692-3383	Edward Bates 513-569-7774	Acid Mine Drainage	Metals	Not Applicable

* An additional demonstration is planned for this technology. Refer to the profile in the Demonstration Program (completed projects) section for more information.

** Solicitation Number

*** From Emerging Technology Program

TABLE 2 (continued)
Ongoing SITE Demonstration Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
EET, Inc., Bellaire, TX (009)	Extraction of PCBs from Porous Surfaces Using the TECHXTRACT™ Process	Tim Tarrillion 713-662-0727	Richard Eilers 513-569-7809	Solids	Heavy Metals, Radionuclides	PCBs, Hydrocarbons
Electrokinetics Inc.,*** Baton Rouge, LA (009)/(E03)	Electro-Klean™ Electrokinetic Soil Processing	Yalcin Acar and Robert Marks 504-388-3992	Randy Parker 513-569-7271	Soil	Heavy Metals and Other Inorganics, Radionuclides	Nonspecific Organics
EnviroMetal Technologies Inc., Guelph, Ontario, Canada (008)	In Situ Metal Enhanced Abiotic Degradation of Dissolved Halogenated Organic Compounds in Groundwater	John Vogan 519-824-0432	Chien Chen 908-906-6985	Groundwater	Not Applicable	Halogenated Organic Compounds
GEOCHEM, A Division of Terra Vac, Lakewood, CO (007)	In Situ Remediation of Chromium in Groundwater	Jim Rouse 303-988-8902	Douglas Grosse 513-569-7844	Groundwater	Hexavalent Chromium, Uranium, Selenium, Arsenic	Not Applicable
Horsehead Resource Development Co., Inc.,* Monaca, PA (008)	Flame Reactor	Regis Zagrocki 412-773-2289	Donald Oberacker 513-569-7510 Marta K. Richards 513-569-7692	Soil, Sludge, Industrial Solid Residues	Metals	Not Applicable
Hydrologics, Inc., Englewood, CO (008)	CURE® - Electrocoagulation Wastewater Treatment System	Carl Dalrymple 303-761-6960	Annette Gatchett 513-569-7697	Water	Aluminum, Arsenic, Barium, Cadmium, Chromium, Cyanide, Lead, Nickel, Uranium, and Zinc	Not Applicable
IT Corporation, San Bernardino, CA (007)	In Situ Groundwater Treatment System	Walter Grinyer 909-799-6869	Michelle Simon 513-569-7469	Groundwater	Not Applicable	VOCs
Matrix Photolytic Inc. (formerly Nutech Environmental),*** London, Ontario, Canada (009)/(E05)	Photocatalytic Water Treatment	Bob Henderson 519-660-8669	Richard Eilers 513-569-7809	Wastewater, Groundwater, Process Water	Nonspecific Inorganics	PCBs, PCDDs, PCDFs, Chlorinated Alkenes, Chlorinated Phenols

* An additional demonstration is planned for this technology. Refer to the profile in the Demonstration Program (completed projects) section for more information.
*** From Emerging Technology Program

TABLE 2 (continued)

Ongoing SITE Demonstration Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Morrison Knudsen Corporation/ Spetstamponazhgeologia Enterprises (STG), Boise, ID (009)	High Clay Grouting Technology	Kathryn Levihn or R. Mac Hartley 208-386-6115	Jack Hubbard 513-569-7507	Groundwater	Heavy Metals	Nonspecific Organics
New York State Department of Environmental Conservation, Albany, NY (009)	Multi-Vendor Bioremediation	Nick Kolak 518-485-8792	Annette Gatchett 513-569-7697	Soil	Not Applicable	VOCs
North American Technologies Group, Inc., Sacramento, CA (008)	BioTreat™ System	Cathryn Wimberly 916-366-6165	Mary Stinson 908-321-6683	Soil, Sludge, Mixed Media	Not Applicable	Gasoline, Jet Fuel, Diesel Fuel, Motor Oil, Crude Oil, PAHs, BTEX, Methyl Isobutyl Ketone, TCE, PCP, Creosotes
Pintail Systems Incorporated, Aurora, CO (009)	Spent Ore Bioremediation Process	Leslie Thompson 303-367-8843	Jack Hubbard 513-569-7507	Spent Ore Heaps, Waste Rock Dumps, Mine Tailings, Process Water	Cyanide	Not Applicable
Praxis Environmental Technologies, Inc., Burlingame, CA (008)	In Situ Thermal Extraction Process	Lloyd Stewart 415-548-9288 Paul Carpenter 904-283-6187	Paul dePercin 513-569-7797	Soil, Groundwater	Not Applicable	VOCs and SVOCs, Hydrocarbons, Solvents
Process Technologies, Inc., Boise, ID (009)	Photolytic Destruction for SVE Off-Gases	Mike Swan 208-385-0900 Steve Hodge 916-643-0830	Laurel Staley 513-569-7863	Air, Gases	Not Applicable	VOCs, Chlorinated VOCs, CFCs
Purus, Inc., San Jose, CA (006)	PurCycle™ Vapor Treatment Process	Bart Mass 408-955-1000	Norma Lewis 513-569-7665	Soil, Groundwater, Air	Not Applicable	Fuel Hydrocarbons, VOCs, SVOCs, Chlorinated Solvents
Remediation Technologies, Inc., Seattle, WA (002)	Liquid and Solids Biological Treatment	Merv Cooper 206-624-9349	Ronald Lewis 513-569-7856	Soil, Sediment, Sludge	Not Applicable	Biodegradable Organics, Creosote, PCP, PAHs

TABLE 2 (continued)

Ongoing SITE Demonstration Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Risk Reduction Engineering Laboratory,* Cincinnati, OH (009)	Base-Catalyzed Decomposition Process	Carl Brunner 513-569-7655 Yei-Shong Shieh or G. Steven Detwiler 610-832-0700	Terrence Lyons 513-569-7589	Soil, Sediment, Sludge	Not Applicable	PCBs, PCPs, Halogenated Compounds
Risk Reduction Engineering Laboratory, Cincinnati, OH (006)	Bioventing	Paul McCauley 513-569-7444	Jack Hubbard 513-569-7507	Soil	Not Applicable	Biodegradable Organics
RKK, Ltd., Arlington, WA (009)	CYROCELL™	Christopher Reno 206-653-4844	Annette Gatchett 513-569-7697	Soil, Groundwater, Leachate	Non-specific Inorganics	Non-specific Organics
Sandia National Laboratory,**** Albuquerque, NM (009)	Electrokinetic Extraction in Unsaturated Soils	Eric Lindgren 505-844-3820	Randy Parker 513-569-7271	Soil	Hexavalent Chromium	Not Applicable
Separation and Recovery Systems, Inc., Irvine, CA (002)	SAREX Chemical Fixation Process	Brad Miller 714-261-8860	Jack Hubbard 513-569-7507	Soil, Sludge	Low-Level Metals	Nonspecific Organics
Sevenson Environmental Services, Inc., Munster, IN (009)	MAECTITE® Chemical Treatment Process	Karl Yost 219-836-0116	Jack Hubbard 513-569-7507	Soil, Sludge, Sediment, Solids	Lead, Other Heavy Metals	Not Applicable
SIVE Services, Dixon, CA (009)	Steam Injection and Vacuum Extraction-Linear Flow (SIVE-LF) Process	Douglas Dieter 916-678-8358	Michelle Simon 513-569-7469	Soil	Not Applicable	VOCs, SVOCs
TechTran Environmental, Inc., Houston, TX (005)	Combined Chemical Precipitation, Physical Separation, and Binding Process for Radionuclides and Heavy Metals	E.B. (Ted) Daniels 713-680-8833	Annette Gatchett 513-569-7697	Water, Soil, Sludge	Heavy Metals, Radionuclides	Not Applicable
TriWaste Reduction Services, Inc.,**** Calgary, Alberta, Canada (009)	Thermal Phase Separator and TRACE Soil Washing Unit	Phil Carson 403-234-3229	Gordon Evans 513-569-7684	Soil	Copper, Lead, Zinc	Chlorinated Compounds, PCBs, Hydrocarbons

* An additional demonstration is planned for this technology. Refer to the profile in the Demonstration Program (completed projects) section for more information.
*** From Emerging Technology Program
**** This technology is not profiled in this document. For further information, please contact the Technology Contact or the EPA Project Manager.

TABLE 2 (continued)

Ongoing SITE Demonstration Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Vortec Corporation,*** Collegeville, PA (009)/(E04)	Oxidation and Vitrification Process	James Hnat 610-489-2255	Teri Richardson 513-569-7949	Soil, Sludge, Sediment, Mill Tailings	Metals, Other Nonspecific Inorganics	Nonspecific Organics
Western Research Institute,*** Laramie, WY (005)/(E01)	Contained Recovery of Oily Wastes (CROW™)	Lyle Johnson 307-721-2281	Eugene Harris 513-569-7862	Soil, Water	Not Applicable	Coal Tar Derivatives, Petroleum By-products, PCP
Wheelabrator Technologies Inc., Hampton, NH (008)	WES-PHix Stabilization Process	Mark Lyons 603-929-3000	Chien Chen 908-321-6985	Municipal Waste Combustion Ash, Soil, Sludge	Heavy Metals, Lead, Cadmium, Copper, Zinc	Not Applicable
Xerox Corporation, Webster, NY (009)	Two-Phase Extraction Process	Ron Hess 716-422-3694 Bud Hoda 916-643-1742	Laurel Staley 513-569-7863	Groundwater, Soil	Not Applicable	VOCs
Zenon Environmental Inc.,*** Burlington, Ontario, Canada (007)/(E02)	Cross-Flow Pervaporation System	Philip Canning 905-639-6320	Ronald Turner 513-569-7775	Groundwater, Lagoons, Leachate, Rinsewater	Not Applicable	Solvents, Degreasers, Gasoline, VOCs
Zenon Environmental Inc., Burlington, Ontario, Canada (007)	ZenoGem™ Process	Tony Tonelli 905-639-6320	Daniel Sullivan 908-321-6677	Groundwater, Leachate	Not Applicable	Nonspecific Biodegradable Organics
Zimpro Environmental, Inc., Rothschild, WI (002)	PACT® Wastewater Treatment System	William Copa 715-359-7211	John Martin 513-569-7758	Groundwater, Industrial Wastewater, Leachate	Not Applicable	Biodegradeable VOCs and SVOCs

*** From Emerging Technology Program

ALLIEDSIGNAL ENVIRONMENTAL SYSTEMS AND SERVICES
(Immobilized Cell Bioreactor Biotreatment System)

TECHNOLOGY DESCRIPTION:

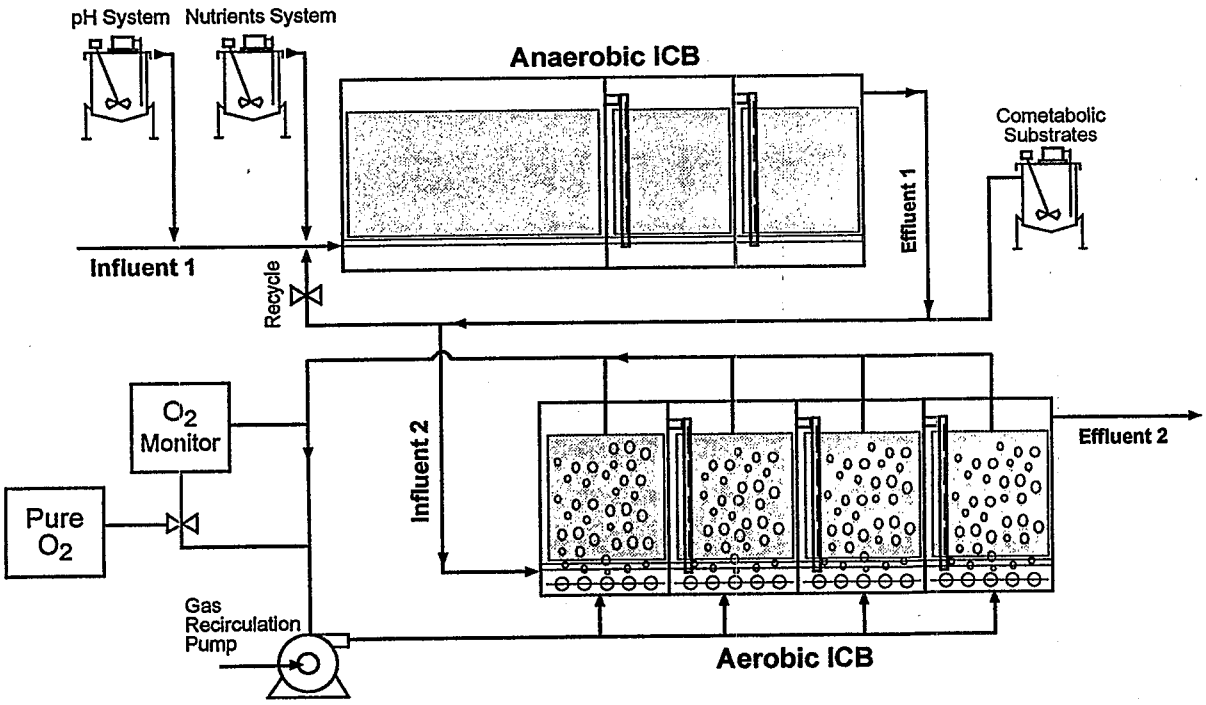
The immobilized cell bioreactor (ICB) biotreatment system is an aerobic, anaerobic, or combined aerobic/anaerobic fixed-film bioreactor system designed to remove organic contaminants (including nitrogen-containing compounds and chlorinated solvents) from process wastewater, contaminated groundwater, and other aqueous streams. This biotreatment system offers improved treatment efficiency by using 1) a unique, proprietary reactor medium that maximizes biological activity in the reactor, and 2) a proprietary reactor design that maximizes contact between the biofilm and the contaminants. These features result in quick, complete degradation of target contaminants to carbon dioxide, water, and biomass. Additional advantages include 1) high treatment capacity, 2) compact system design, and 3) reduced operations and maintenance costs resulting from simplified operation and low sludge production.

Basic system components include the bioreactor(s), media, mixing tanks and pumps, feed pump, recirculation pump, and a blower to provide air to the aerobic bioreactor. The figure below is a schematic of the system.

Depending on the specifics of the influent streams, some standard pretreatments, such as pH adjustment or oil and water separation, may be required. Effluent clarification is not required for the system to operate, but may be required to meet specific discharge requirements. The system is designed to treat 10 million gallons per day of contaminated aqueous streams.

WASTE APPLICABILITY:

The ICB biotreatment system has been successfully applied to industrial wastewater and groundwater containing a wide range of organic



Dual Anaerobic/Aerobic ICB Flow Diagram

The SITE Program assesses but does not approve or endorse technologies.

contaminants, including polynuclear aromatic hydrocarbons (PAH), phenols, gasoline, chlorinated solvents, diesel fuel, and chlorobenzene. Industrial streams amenable to treatment include wastewaters generated from chemical manufacturing, petroleum refining, wood treating, tar and pitch manufacturing, food processing, and textile fabricating. AlliedSignal, Inc., has obtained organic chemical removal efficiencies of greater than 99 percent. The ICB biotreatment system, because of its proprietary medium, is also very effective in remediating contaminated groundwater streams containing trace organic contaminants.

The ICB biotreatment system can be provided as a complete customized facility for specialized treatment needs or as a packaged modular unit. The technology can be retrofitted to existing bioreactors by adding the necessary internal equipment and proprietary media. The table below summarizes recent applications.

Applications	Contaminants	Scale
• Pipeline Terminal Wastewater	• Chemical oxygen demand, Benzene, Methyl Tertiary Butyl Ether (MTBE), Xylenes	• Commercial
• Specialty Chemical Wastewater	• Cresols, MTBE, PAH, Phenolics	• Commercial
• Groundwater	• Chlorobenzene, TCE	• Pilot
• Coal Tar Distillation Plant Wastewater	• Phenol, Cyanide, Ammonia	• Commercial
• Wood Treating Wastewater	• Phenolics, Creosote	• Commercial

STATUS:

A dual ICB anaerobic/aerobic system for bioremediation of chlorinated solvents will be demonstrated in the near future at a site contaminated with trichloroethene (TCE) in St. Joseph, Michigan.

This biotreatment system has a completely enclosed headspace, eliminating the possibility of air stripping of volatile organics or intermediates. The process was tested both in the laboratory and at pilot scale and reduced high levels of TCE (greater than 100 ppm) to low parts-per-billion levels.

A Demonstration Plan will be developed in 1994; the demonstration will be conducted at a later date.

FOR FURTHER INFORMATION:

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Fax: 201-455-5722

The SITE Program assesses but does not approve or endorse technologies.

ANDCO ENVIRONMENTAL PROCESSES, INC.
(Electrochemical In Situ Chromate Reduction and Heavy Metal Immobilization)

TECHNOLOGY DESCRIPTION:

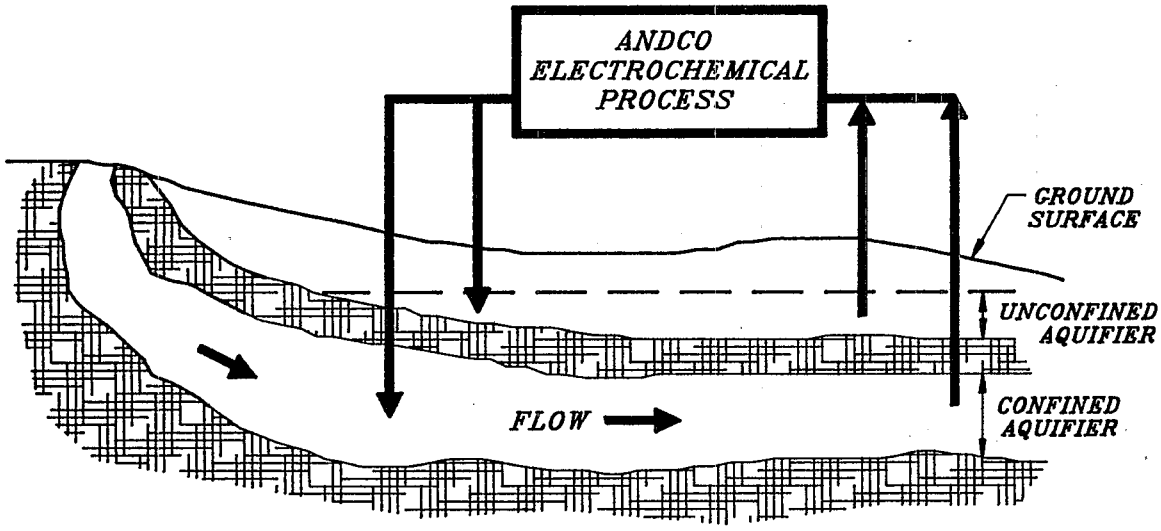
The electrochemical in situ chromate reduction and heavy metal immobilization process uses electrochemical reactions that generate ions for removal of hexavalent chromium and other metals from groundwater. With regard to hexavalent chromium, as contaminated water is pumped from an aquifer though the treatment cell (see figure below), electrical current passes from electrode to electrode through the process water. The electrical exchange induces the release of ferrous and hydroxyl ions from opposite sides of each electrode. A small gap size, coupled with the electrode potentials of hexavalent chromium and ferrous ion, cause an almost instantaneous reduction of hexavalent chromium.

Depending on the groundwater's pH, various solids may form. These solids include chromium hydroxide, hydrous ferric oxide, and a chromium-substituted hydrous iron complex.

For in situ chromate reduction to occur, a slight excess of ferrous iron must be provided. This ferrous iron concentration is determined based on 1) the hexavalent chromium concentration in the groundwater, 2) site-specific hydraulics, and 3) the target rate of site cleanup.

Dilution is avoided by introducing ferrous ions in situ and using the aquifer's water to convey them. Following injection, soluble ferrous ions circulate until they contact chromate containing solids or chromate ions. In conventional pump-and-treat schemes, chromate dragout results in long treatment times. Through in situ reduction of chromates that are adsorbed on the soil matrix and contained in precipitates, treatment times should be reduced by more than 50 percent.

If implemented properly under favorable pH conditions, chromate can be completely reduced without producing sludge. As chromate reduction occurs, iron and chromium solids are filtered out and stabilized in the soil. When



Electrochemical In Situ Chromate Reduction and Heavy Metal Immobilization Process

The SITE Program assesses but does not approve or endorse technologies.

precipitates do not form due to unfavorable pH, the system can easily be operated as part of a pump-and-treat process until chromium removal goals are achieved. Eliminating dragout shortens cleanup time and minimizes sludge handling. Another option is to combine a pump-and-treat scheme with in situ chromate reduction to maximize the cleanup rate, reduce aquifer contaminant loads, and provide water for irrigation or industry.

Another benefit of this reduction method is that hydrous iron oxide adsorbs heavy metals. When iron solids are immobilized in the soil, concentrations of other metallic contaminants in the groundwater decrease significantly due to adsorption and coprecipitation.

WASTE APPLICABILITY:

A pilot-scale process unit has been designed to treat groundwater contaminated with hexavalent chromium ranging from 1 to 50 parts per million (ppm) and other heavy metals (2 to 10 ppm), including zinc, copper, nickel, lead, and antimony. A full-scale system can be engineered to handle any flow rate as well as elevated contaminant loads. Each system will be designed to achieve all site-specific remediation objectives.

STATUS:

This technology was accepted into the SITE Demonstration Program in June 1992. Sites are being screened for the demonstration in EPA Regions 2 and 10. Although the process can remediate both confined and unconfined aquifers, water from an unconfined source will be treated during the demonstration.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
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Andco Environmental Processes, Inc.
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Buffalo, NY 14228-2380
716-691-2100
Fax: 716-691-2880

The SITE Program assesses but does not approve or endorse technologies.

APROTEK
(Ion Conduction Agglomeration System)

TECHNOLOGY DESCRIPTION:

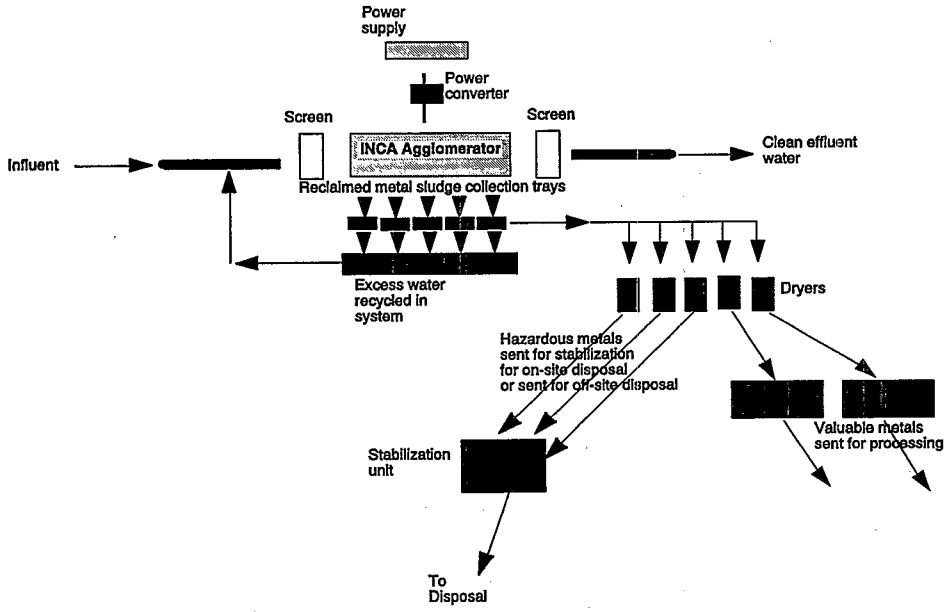
The high tension Ion Conduction Agglomeration (INCA) system is an electrolytic recovery process that removes or recovers soluble and particulate metals from aqueous solutions such as mining effluents, process waters, and wastewaters. Each INCA module is individually configured to recover a desired element or series of elements in a separate stream. This adaptability is particularly important when the waste stream contains a combination of valuable and hazardous materials, common in mining effluent.

The standard flow-through system is a modular unit that can process up to 2,000 gallons per minute. Larger volumes can be processed by increasing unit size or adding additional modules.

The INCA system includes an ion destabilizer that features a unique anode and cathode configuration. Unlike other types of electrolytic technologies in which the cathodes are made of stainless steel, INCA system cathodes are made of a specially-coated material. Proprietary coatings are grafted on the tubular collection units; these coatings are specific to the metals to be collected by the system. When power is applied, the applicable metallic ions in the solution destabilize and agglomerate to the tubes.

The metals are collected on a special plate system, where they are consolidated into a sludge and fall into a collection vessel. The sludges, which contain approximately 66 percent water, are drained and dried in a drum dryer. The remaining metal powder is sent for processing or disposal as appropriate.

The INCA system can process aqueous solutions efficiently and greatly reduces costs for two major reasons: 1) the technology costs much less than traditional treatment methods, and 2) the value of precious metals recovered during the process may offset the cost of remediation



INCA System

The SITE Program assesses but does not approve or endorse technologies.

and could turn the treatment system into a profit center.

WASTE APPLICABILITY:

The INCA system can recover virtually any target metal in any aqueous waste stream containing up to 60 percent solids. Applications include on-site remediation for mining effluents and contaminated groundwater. The INCA system can also be used as an in-process treatment system for manufacturing processes where metals in solution are a problem. The modular unit can easily be used in tandem with other technologies, such as those that remove hydrocarbons, to constitute a total treatment train.

STATUS:

This technology was accepted into the SITE Demonstration Program in February 1993. A SITE demonstration is scheduled for late 1994. The location of the demonstration has not been identified.

FOR FURTHER INFORMATION:

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Aprotek
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Fax: 916-366-7873

The SITE Program assesses but does not approve or endorse technologies.

ASI ENVIRONMENTAL TECHNOLOGIES, INC./ DAMES & MOORE
(Hydrolytic Terrestrial Dissipation)

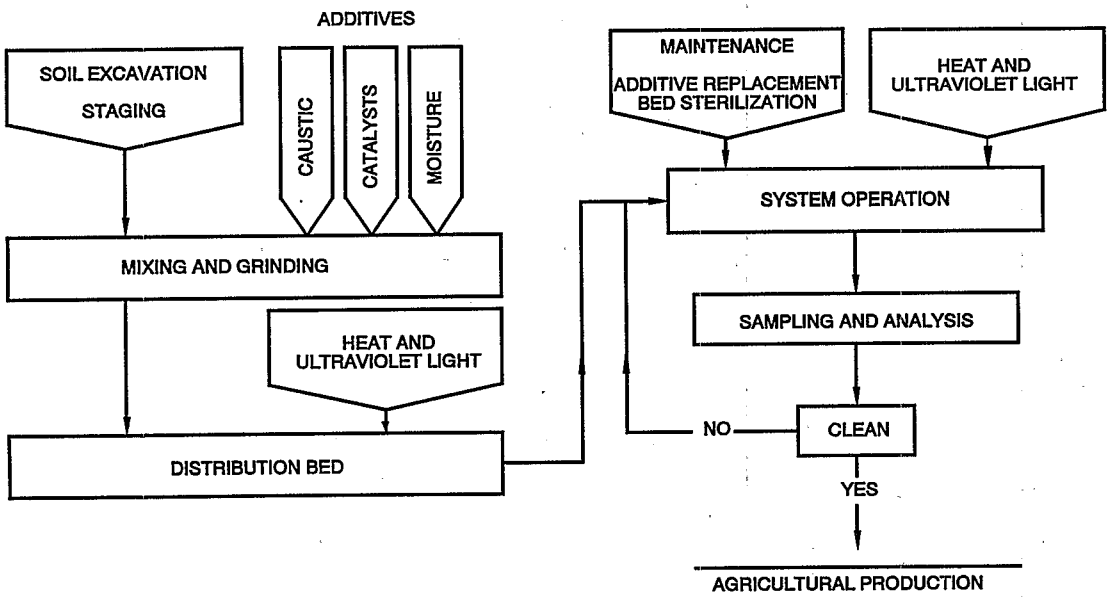
TECHNOLOGY DESCRIPTION:

The Hydrolytic Terrestrial Dissipation (HTD) process was developed for use at the Chemairspray site in Palm Beach County, Florida. An estimated 11,500 cubic yards of surface soils at the site are contaminated with toxaphene (a chlorinated pesticide) and metal fungicides, primarily copper.

After excavation, the HTD process mixes and grinds soils to uniformly distribute metal complexes and organic chemicals. During mixing, caustics are added to raise the soil pH to 8.0 or greater, although slower reactions should still occur at lower pHs. Soil moisture levels are maintained during mixing to prevent adsorption and fugitive dust.

The prepared mixture is then distributed in a thin veneer (4 to 7 centimeters) over a soil bed and exposed to heat and ultraviolet (UV) light from the sun to facilitate dissipation. Sodium metabisulfite (a reducing agent), caustics, and moisture are added at intervals to maintain the reactions and ensure that metal catalysts are available to further the hydrolysis. As hydrolysis proceeds, toxaphene with 5 to 11 chlorine atoms per molecule transforms to lower molecular weights through dechlorination and other processes. UV light within the visible spectrum is also known to cleave the carbon-chloride bond as well as other chemical bonds. As lower weight toxaphene moieties occur at the surface of the soil mixture, the molecular structure should further degrade to still lower weight compounds.

HTD uses metal-catalyzed alkaline hydrolysis reactions with a reducing agent to liberate chlorine ions from the toxaphene's molecular structure. Depending on numerous factors, including the nature of the contaminated media, liberated chlorine ions probably mineralize in the soil. HTD is a slowly occurring process that should degrade toxaphene to camphene ($C_{10}H_{16}$) or



Hydrolytic Terrestrial Dissipation

The SITE Program assesses but does not approve or endorse technologies.

similar innocuous compounds, which ultimately break down to water and other carbon oxides (CO_x). The figure on the previous page illustrates the process.

Soils in the distribution bed are periodically sampled to evaluate any residual contamination. Also, the quality of underlying groundwater is monitored during operation. After treated soils meet established criteria, the land may be returned to beneficial use. One staging unit can treat about 5,000 to 6,000 cubic yards per year.

WASTE APPLICABILITY:

HTD is a process designed around the physical chemistry of the contaminant and its environment. Depending upon the site and contaminant, metal catalysts, reducing (or perhaps oxidizing) compounds, conditions of the process, and other parameters may be altered within the HTD design to provide effective treatment under a wider range of applications. HTD's current design can treat large amounts of soil contaminated by small amounts (less than 1 percent) of toxaphene and other pesticides. The physical chemistry of the target contaminants dictates modifications for other applications; however, the process should only be designed with sufficient time for reactions to occur. Although set-up for HTD implementation may be reasonably inexpensive compared with other remedial programs, the process can require large amounts of land for its distribution bed. Of its potential applications, agricultural or other large land uses are currently preferable sites. HTD may also have applications when coupled with other passive technologies, such as bioremediation, to provide an integrated remedial activity.

STATUS:

The HTD process was accepted into the SITE Demonstration Program in spring 1991. A simulation tank has been constructed to evaluate hydrolysis under laboratory conditions. A quality control program validated laboratory results.

Soil moisture may play a major role in releasing toxaphene from its bound state and allowing degradation. Treatability studies were conducted with soil moisture at about 50 percent, soil pH at 8.5, air temperature at 102 to 105 degrees Fahrenheit, and a UV wavelength of 356 nanometers (nm).

Under simulated conditions, these studies also show that HTD methods slowly degrade organochlorine and other pesticides in contaminated soils. Additional studies under similar conditions that include a reducing agent and slightly higher frequency UV light (256 nm), show that it is possible to enhance and accelerate toxaphene's degradation reactions.

FOR FURTHER INFORMATION:

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The SITE Program assesses but does not approve or endorse technologies.

COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT
(Developed by COLORADO SCHOOL OF MINES)
(Wetlands-Based Treatment)

TECHNOLOGY DESCRIPTION:

The constructed wetlands-based treatment technology uses natural geochemical and biological processes inherent in a man-made wetland ecosystem to accumulate and remove metals from influent waters (see figure below). The treatment system incorporates principal ecosystem components found in wetlands, including organic materials (substrate), microbial fauna, and algae.

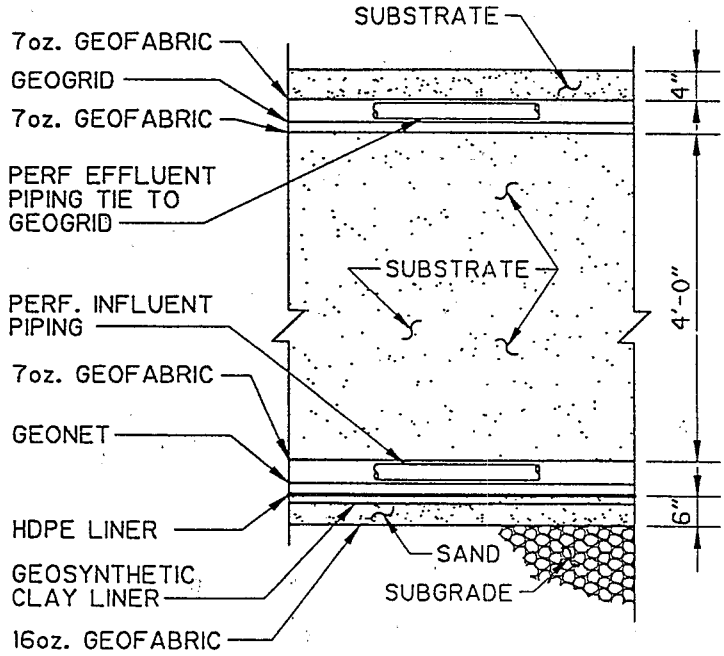
Influent waters, with low pH and contaminated with high metal concentrations, flow through the aerobic and anaerobic zones of the wetland ecosystem. Metals are removed by ion exchange, adsorption, absorption, and precipitation by geochemical and microbial oxidation and reduction. Ion exchange occurs as metals in the water contact humic or other organic substances in the soil medium. Oxidation and reduction reactions that occur in the aerobic and anaerobic zones, respectively, precipitate metals as hydroxides and sulfides. Precipitated and adsorbed metals settle in quiescent ponds, or are filtered out as the water percolates through the soil or substrate.

WASTE APPLICABILITY:

The wetlands-based treatment process is suitable for acid mine drainage from metal or coal mining activities. These wastes typically contain high metals concentrations and low pH. Wetlands treatment has been applied with some success to wastewater in the eastern United States. The process may have to be adjusted to account for differences in geology, terrain, trace metal composition, and climate in the metal mining regions of the western United States.

STATUS:

Based on the SITE Emerging Technology Program results, this process has been selected for the SITE Demonstration Program.



Schematic Cross Section of Upflow Pilot Cell

The SITE Program assesses but does not approve or endorse technologies.

The project's final year under the Emerging Technology Program was 1991. Study results of drainage from the Big Five Tunnel near Idaho Springs, Colorado indicated that removal efficiency of heavy metals can approach the removal efficiency of chemical precipitation treatment plants.

A final goal of the Emerging Technology Program project was developing a manual that discusses design and operating criteria for constructing a full-scale wetland to treat acid mine discharges. The "Wetland Designs for Mining Operations" manual is available from the National Technical Information Service.

The Demonstration Program is currently evaluating the effectiveness and biogeochemical processes at the Burleigh Tunnel mine discharge, near Silver Plume, Colorado. Treatment of the Burleigh Tunnel is part of the remedy for the Clear Creek Central City Superfund site. Construction of a pilot treatment system began in summer 1993 and was completed in October 1993.

The pilot treatment system is approximately 4200 square-feet and consists of an upflow (see figure on previous page) and downflow cell. Each cell is treating about 10 gallons per minute of flow. Preliminary results indicate high removal efficiency (greater than 90 percent) for zinc, the primary contaminant in the discharge.

FOR FURTHER INFORMATION:

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The SITE Program assesses but does not approve or endorse technologies.

EET, INC.
(Extraction of Polychlorinated Biphenyls from Porous Surfaces Using the TECHXTRACT™ Process)

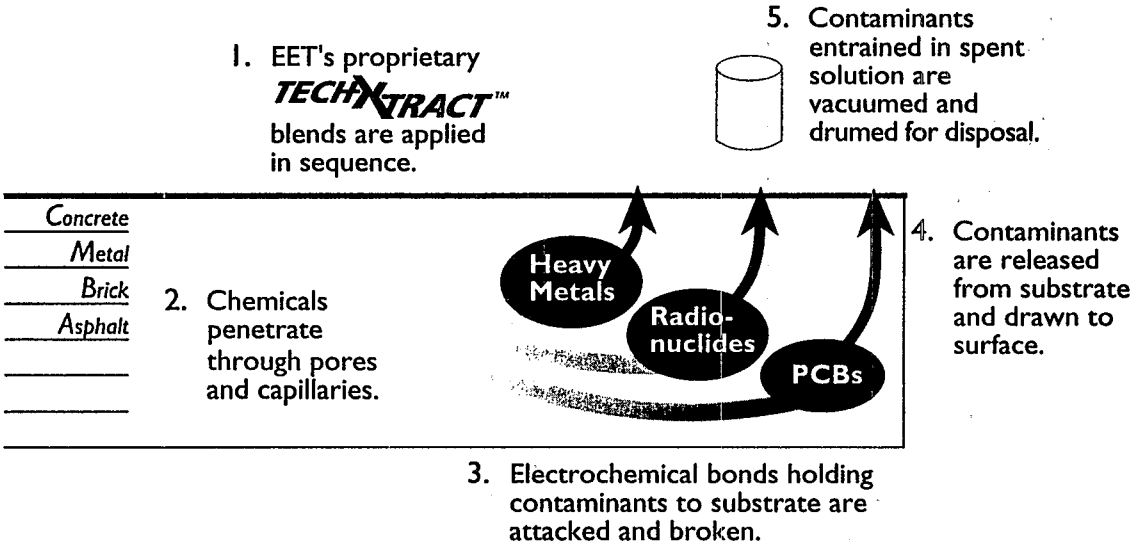
TECHNOLOGY DESCRIPTION:

The TECHXTRACT™ process employs proprietary chemical formulations in successive steps to remove polychlorinated biphenyls (PCB), toxic hydrocarbons, heavy metals, and radionuclides from the subsurface of porous materials such as concrete, brick, steel, and wood. Each formulation consists of chemicals from up to 14 separate chemical groups, and can be specifically tailored to each contaminated site.

The process is performed in multiple cycles, and each cycle includes three stages: surface preparation, extraction, and rinsing. Each stage employs a specific chemical mix.

The surface preparation step uses a solution that contains buffered organic and inorganic acids, sequestering agents, wetting agents, and special hydrotrope chemicals. The extraction formula includes macro- and microemulsifiers in addition to electrolyte, flotation, wetting, and sequestering agents. The rinsing formula is pH-balanced and contains wetting and complexing agents. Emulsifiers in all the formulations help eliminate fugitive releases of volatile organic compounds or other vapors.

The formulation in each stage is sprayed on the contaminated surface as a fine mist and worked into the surface with a stiff bristle brush or floor scrubber. The chemicals are allowed to pene-



Schematic Diagram of the TECHXTRACT™ Process

The SITE Program assesses but does not approve or endorse technologies.

trate into the subsurface, and are then rinsed or vacuumed from the surface with a high-efficiency particulate air-filtered barrel-vacuum. No major capital equipment is required.

Contaminant levels can be reduced from 60 to 90 percent per cycle. One cycle can take up to 24 hours. The total number of cycles is determined from initial contaminant concentrations and final concentration target levels.

WASTE APPLICABILITY:

The TECHXTRACT™ process is designed to treat porous solid materials contaminated with PCBs; toxic hydrocarbons; heavy metals, including lead and arsenic; and radionuclides. By extracting the contaminants from the surface, the materials can be left in place, reused, or recycled. After treatment, the contaminants are concentrated in a small volume of liquid waste.

In commercial applications, the process has reduced PCB concentrations from 1,000,000 micrograms per one hundred square centimeters ($\mu g/100\ cm^2$), to concentrations less than 0.2 $\mu g/100\ cm^2$. TECHXTRACT™ has been used on concrete floors, walls, and ceilings, tools and machine parts, internal piping, valves, and lead shielding. TECHXTRACT™ has removed lead, arsenic, technetium, uranium, cesium, tritium, and thorium.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1994, with an expected demonstration date of December 1994. The demonstration should verify PCB extraction depth from concrete surfaces and quantify contaminant removal from the subsurface.

The technology has been used in over 200 successful decontamination projects for the U.S. Department of Energy, U.S. Department of Defense, electric utility industry, heavy manufacturing industry, steel industry, aluminum industry, and other applications. Further research is underway to apply the technology on soil, gravel, and other loose material. Additional research is planned to remove or concentrate metals in the extracted liquids.

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The SITE Program assesses but does not approve or endorse technologies.

ELECTROKINETICS INC.
(Electro-Klean™ Electrokinetic Soil Processing)

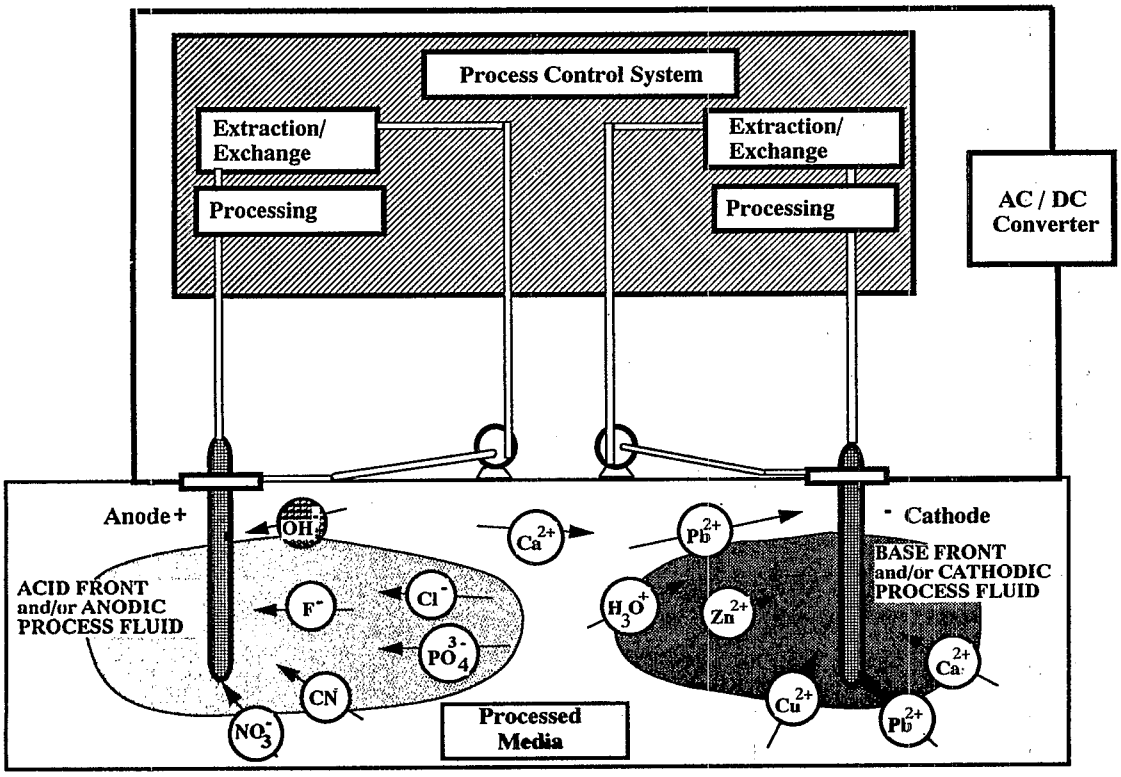
TECHNOLOGY DESCRIPTION:

The Electro-Klean™ electrokinetic soil process separates and extracts heavy metals and organic contaminants from soils. Electro-Klean™ can be applied in situ or ex situ, and uses direct currents with electrodes placed on each side of the contaminated soil mass. Conditioning fluids such as suitable acids may be used for electrode (cathode) depolarization to enhance the process.

The figure below illustrates the field processing scheme and the flow of ions to respective bore boles (or trenches). Conditioning pore fluids may be added or circulated at the electrodes to control process electrochemistry. Contaminants are electroplated on the electrodes or separated in a posttreatment unit.

An acid front migrates towards the negative electrode (cathode) and contaminants are extracted through electrosmosis (EO) and electromigration (EM). The concurrent mobility of the ions and pore fluid decontaminates the soil mass. The EO and EM supplement or replace conventional pump-and-treat technologies.

Bench-scale results show that the process works in both unsaturated and saturated soils. Pore fluid flow moves from the positive electrodes (anodes) to the cathodes under the effect of the EO and EM forces. Electrode selection is important, since many metal or carbon anodes will rapidly dissolve from attack of strong oxidants.



Electrokinetic Remediation Process

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

Electro-Klean™ extracts heavy metals, radionuclides, and other inorganic contaminants below their solubility limit. Bench-scale tests have removed arsenic, benzene, cadmium, chromium, copper, ethylbenzene, lead, nickel, phenol, trichloroethene, toluene, xylene, and zinc from soils. Bench-scale studies under the SITE Program demonstrated the feasibility of removing uranium and thorium from kaolinite.

Limited pilot-scale field tests resulted in zinc and arsenic removal from clays and saturated and unsaturated sandy clay deposits. Lead and copper were also removed from dredged sediments. Treatment efficiency depended on the specific chemicals, their concentrations, and the buffering capacity of the soil. The technique proved 85 to 95 percent efficient when removing phenol at concentrations of 500 parts per million. In addition, the removal efficiency for lead, chromium, cadmium, and uranium at levels up to 2,000 micrograms per gram (μg/g), ranged between 75 and 95 percent.

STATUS:

Bench-scale laboratory studies investigating heavy metal, radionuclide, and organic contaminant removal are complete, and radionuclide removal studies are complete under the SITE Emerging Technology Program. A pilot-scale laboratory study investigating removal of 2,000 μg/g lead loaded onto kaolinite was completed in May 1993. Removal efficiencies of 90 to 95 percent were obtained. The electrodes were placed 3 feet apart in a 2-ton kaolinite specimen for 4 months, at an energy cost of about $15 per ton. The results of a second pilot-scale laboratory study using 5000 μg/g of lead adsorbed on kaolinite showed similar efficiency results as the earlier study. Bench-scale treatability studies and process enhancement schemes using conditioning fluids continue. Ongoing pilot-scale studies and a field study demonstrating lead removal from a military firing range will be conducted during 1994 and 1995; a new electrical separation process of extractive electrolysis will be pilot-tested for removal of multiple heavy metals.

Based on results from the Emerging Technology Program, the Electro-Klean™ soil process was invited to participate in the SITE Demonstration Program. A suitable demonstration site is being sought.

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The SITE Program assesses but does not approve or endorse technologies.

ENVIROMETAL TECHNOLOGIES INC.
(In Situ Metal Enhanced Abiotic Degradation of Dissolved Halogenated Organic Compounds in Groundwater)

TECHNOLOGY DESCRIPTION:

This remedial technology, developed by the Waterloo Center for Groundwater Research and EnviroMetal Technologies, Inc., dehalogenates dissolved halogenated organic compounds in groundwater with an in situ permeable wall containing reactive metal (iron) that is installed across a contaminant plume (see figure below). As the water passes through the wall, the halogenated organics are degraded, preventing contaminants from migrating further downstream.

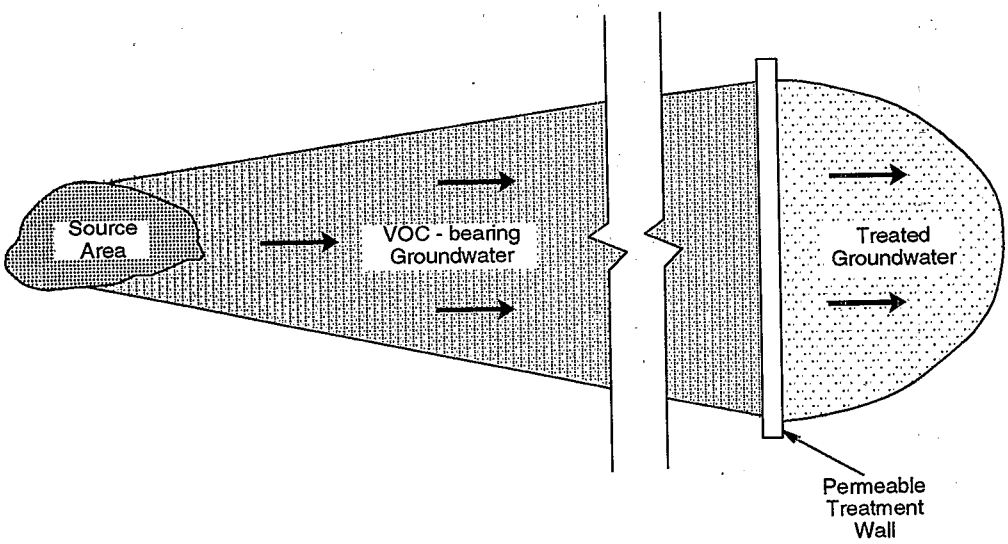
Recent research has indicated that certain zero-valence metals, notably iron, can help degrade a wide variety of dissolved halogenated solvents. The permeable reaction wall contains a specially prepared mixture of iron and an inert support material. Observed degradation rates are several times higher than those reported for natural abiotic degradation processes.

In most in situ applications of this technology, groundwater moves through the permeable wall naturally or is directed by flanking impermeable sections such as sheet piles or slurry walls (see figure on next page). This passive remediation method is a cost-effective alternative to conventional pump-and-treat methods.

Process residuals may include dissolved ethane, ethene, methane, hydrogen gas, and small amounts of chloride and dissolved ferrous iron. Because contaminants are degraded in situ and not transferred to another medium, this process eliminates the need for waste treatment or disposal. Future applications are expected to include aboveground reactor vessels, which may replace or add to conventional pump-and-treat systems.

WASTE APPLICABILITY:

The process was developed to treat dissolved halogenated organic compounds in groundwater. The technology has degraded a wide variety of chlorinated alkanes and alkenes, including trichloroethene (TCE), tetrachlorethene (PCE), vinyl chloride, 1,1,1,-trichloroethane, and 1,2-dichloroethene (DCE). The technology also degrades other organic contaminants, including Freon-113, ethylene dibromide, certain nitro-aromatics, and N-nitrosodimethylamine.



Schematic View of an In Situ Permeable Treatment Wall

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

This technology was accepted into the SITE Demonstration Program in spring 1993. A pilot-scale demonstration of the aboveground reactor technology is scheduled for fall 1994 at an industrial facility in New Jersey, once the groundwater collection system is constructed. The overburden and shallow fractured bedrock beneath the facility contain dissolved TCE and PCE. The flow system prevents installation of a "standard" in situ reactive wall; consequently, groundwater collected in trenches installed in the shallow bedrock will pass through a treatment unit containing a high percentage of iron at a velocity of 5 feet per day.

A second SITE demonstration project is scheduled to begin in New York in winter 1994 or spring 1995. An in situ permeable wall will be installed in a shallow sand aquifer containing TCE, DCE, and 1,1,1-trichloroethane.

A successful permeable in situ wall was installed at the Canadian Forces Base Borden test site in June 1991. Approximately 90 percent of TCE and PCE was removed from groundwater passing through the wall. Over 20 successful bench-scale feasibility tests simulating flow in situ conditions have been completed using groundwater from industrial and government facilities in the United States and Canada.

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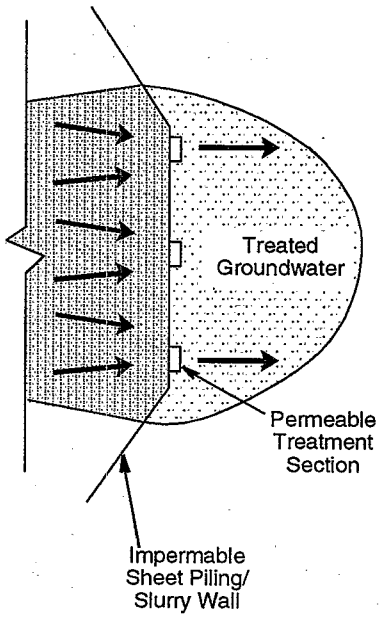


Schematic View of In Situ Permeable Treatment Section Installed in Conjunction with an Impermeable Barrier

The SITE Program assesses but does not approve or endorse technologies.

GEOCHEM, A Division of Terra Vac
(In Situ Remediation of Chromium in Groundwater)

TECHNOLOGY DESCRIPTION:

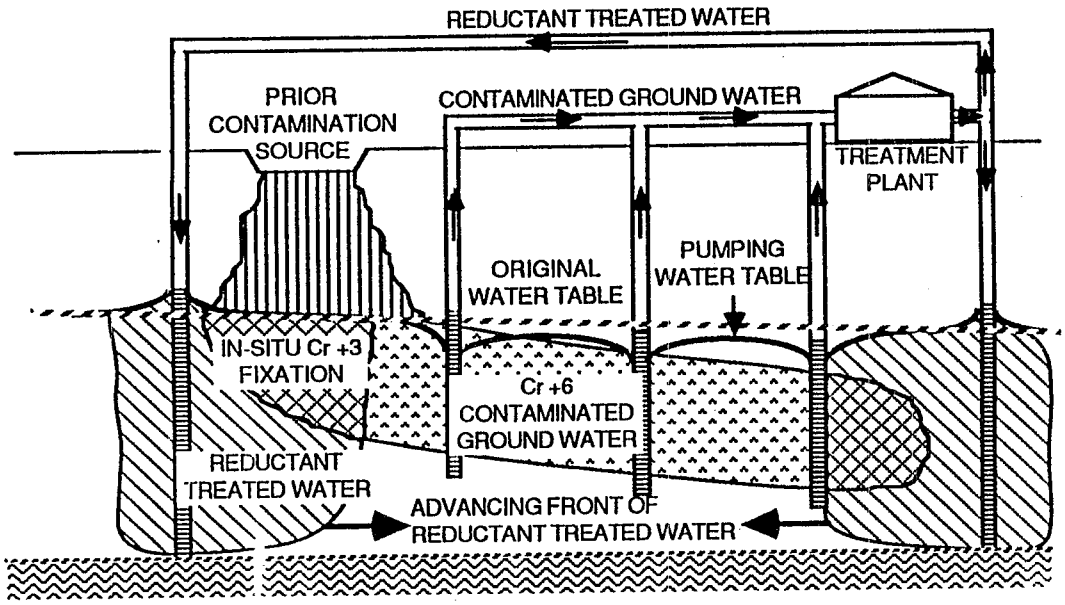
The GEOCHEM treatment process removes chromium from contaminated groundwater using a variation of traditional pump-and-treat methods. As part of GEOCHEM's approach, contaminated groundwater is brought to the surface and treated using conventional treatment systems, such as ferrous ion (see figure below). Next, a reductant is added to the treated water, which is reinjected around the plume margin. Here it reacts with and reduces residual levels of chromium, forming a precipitate. Such reinjection creates a "barrier" of elevated water levels around the plume, enhancing the gradient and associated hydraulic control. The reinjection also allows for in situ reduction and subsequent fixation of residual chromium.

Most aquifer solids naturally contain chromium (primarily trivalent) at levels of 15 parts per million (ppm) or more. The precipitation of residual chromium from the water does not materially add to the concentration of chromium in the aquifer solids since most contaminated zones contain only a few ppm of chromium, and the precipitation of such material onto the aquifer solids does not change the overall chromium concentration in the aquifer.

Geochemical conditions will be evaluated under the SITE Program to ensure that the precipitated chromium does not become remobilized. Data from two different soil treatment approaches are shown on the next page, indicating that using a reductant dosed water is more effective than using demineralized water.

WASTE APPLICABILITY:

The GEOCHEM process is capable of treating dissolved hexavalent chromium in groundwater at concentrations ranging from the detection limit to several hundred ppm. The process is applicable to wood preserving and chromium chemicals manufacturing sites, as well as plating



In Situ Remediation of Chromium in Groundwater

The SITE Program assesses but does not approve or endorse technologies.

and other facilities using hexavalent chromium. In addition, treatment of such groundwater contaminants as uranium, selenium, and arsenic is possible. The technology also has an operational history at mine sites.

STATUS:

GEOCHEM was accepted into the SITE Demonstration Program in summer 1992. Numerous sites were evaluated for demonstrating GEOCHEM's technology. The technique has been accepted by the Indiana Department of Environmental Management for a voluntary full-scale site remediation. Arrangements are being made to demonstrate the technology in early 1995 at the Valley Wood Treating site in Turlock, California. EPA Region 9 has issued notice of intent to apply the technique over the entire Valley Wood site.

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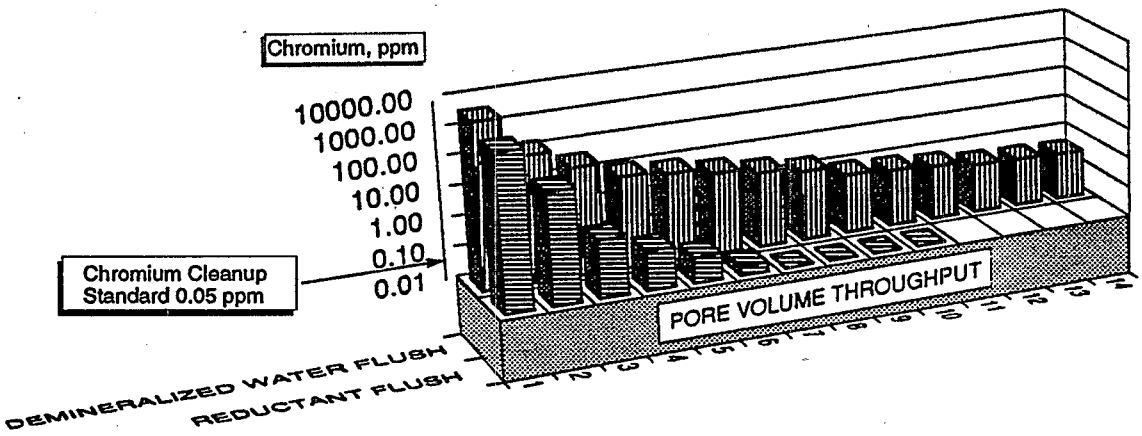


Chromium Reduction as a Function of Water Flush Method and Pore Volume Throughput

The SITE Program assesses but does not approve or endorse technologies.

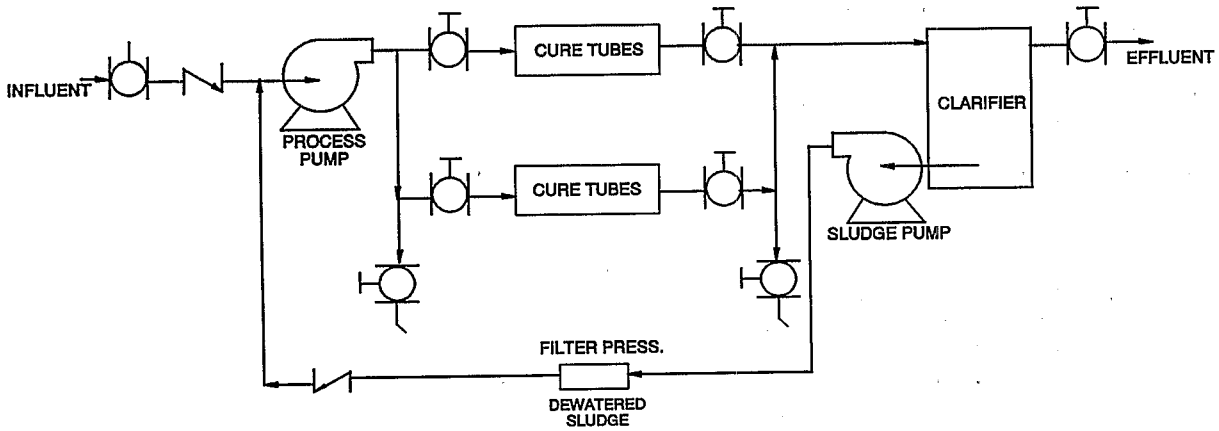
HYDROLOGICS, INC.
(CURE®-Electrocoagulation Wastewater Treatment System)

TECHNOLOGY DESCRIPTION:

The CURE®-Electrocoagulation (CURE®) system is designed to remove ionic metal species and other charged particles from water (see figure below). Because many toxic metal ions including nickel, lead, and chromates are held in solution by electrical charges, they will precipitate out of solution if they are neutralized with oppositely-charged ions. The CURE® system is effective at breaking oily emulsions and removing suspended solids. The CURE® system is an improvement over previous electrocoagulation methods because of a unique geometrical configuration.

The CURE® system patented geometry maximizes liquid surface contact between the anode and concentric cathode electrocoagulation tubes, thus minimizing the power requirements for efficient operation. The CURE® system allows the contaminated water to flow continuously through the cathode tube, enabling a direct current to pass uniformly through a water stream. The contaminated water then passes through the annular space between the cathode and anode tubes and is exposed to sequential positive and negative electrical fields. Typical retention time is less than 20 seconds. Water characteristics such as pH, redox potential, and conductivity can be adjusted to achieve maximum removal efficiencies for specific contaminants.

After the treated water exits the electrocoagulation tubes, the destabilized colloids are allowed to flocculate and are then separated with an integrated clarifier system. Polymers can be added to enhance flocculation, but in most cases they are not required. The sludge produced by this process is usually very stable and acid-resistant. Tests have shown that sludges produced by the CURE® system pass the toxicity characteristic leaching procedure and are often disposed of as nonhazardous waste.



Schematic Diagram of the CURE®-Electrocoagulation System

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The CURE® system is applicable to an extremely broad range of dissolved metals, including aluminum, arsenic, barium, cadmium, chromium, cyanide, lead, nickel, uranium, and zinc. Because electrocoagulation can also remove other suspended materials from solution, this technology can also treat mining, electroplating, industrial wastewaters, and contaminated groundwater. The system can also pretreat water for reverse osmosis systems since it reduces silica, calcium, and suspended solids.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1993. Bench-testing has been completed for a specific site. Negotiations are underway to use this site for the demonstration.

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The SITE Program assesses but does not approve or endorse technologies.

IT CORPORATION
(In Situ Groundwater Treatment System)

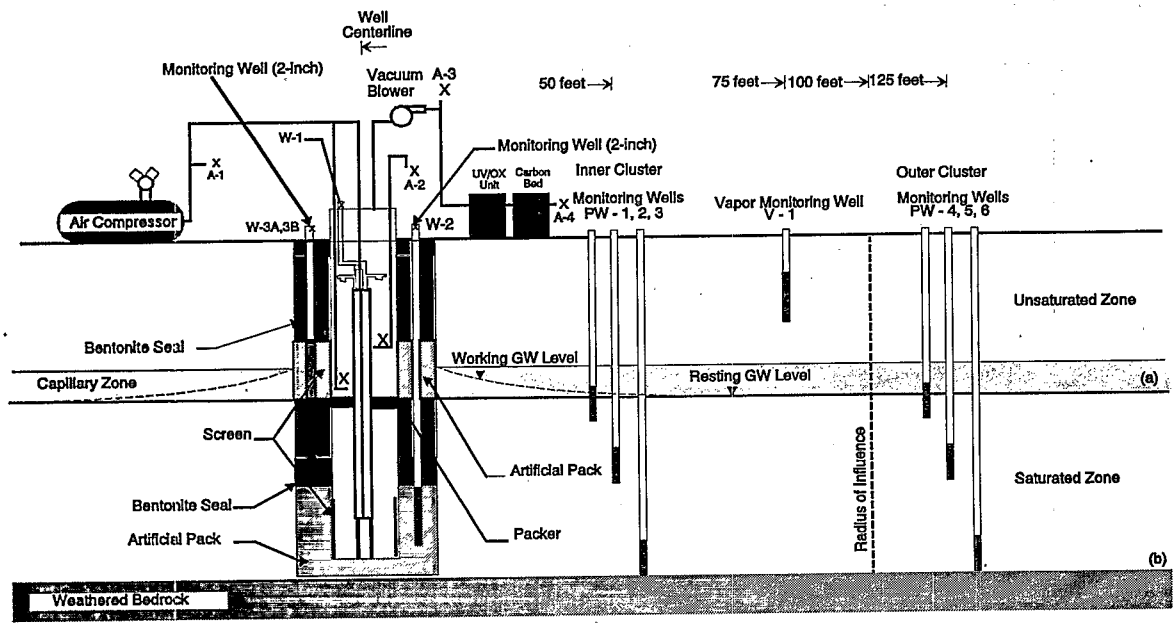
TECHNOLOGY DESCRIPTION:

IT Corporation's in situ groundwater treatment system removes volatile organic compounds (VOC) from groundwater by transferring them to a vapor phase and destroying them with a photocatalytic oxidation (PCO) unit. The halogenated or non-halogenated VOCs may also be additionally treated with granular activated carbon.

The groundwater treatment system consists of three stages: 1) an airlift pumping technique, 2) an in situ vapor stripping method, and 3) air sparging (see figure below). An extraction unit well is installed to the bottom of the contaminated aquifer. Air is injected into an eductor pipe, lifting the contaminated groundwater up through the pipe. The lifting action displaces groundwater from the lower section of the well, replacing it with contaminated groundwater from the lower aquifer.

In the first stage, air bubbles and water mix as they move up the eductor pipe. As the bubbles travel upward, some of the chlorinated VOCs transfer from the water phase to the vapor phase. The vacuum system then removes these vaporized VOCs.

In the second stage, groundwater that has been lifted to the top of the well is sprayed as fine



(a) Depth to water: 55.5 feet
(b) Depth to bedrock: 155 to 161 feet
V-1 set at 75-feet from system well, screened at 15 to 25 feet (bgs)
PW-1 screened from 48.7 to 68.7 feet (bgs)
PW-2 screened from 114 to 124 feet (bgs)
PW-3 screeend from 140 to 155 feet (bgs)
PW-4 screened from 50.3 to 70.3 feet (bgs)
PW-5 screened from 120 to 130 feet (bgs)
PW-6 screened from 150 to 165 feet (bgs)
All cluster wells are set 5 feet apart

NOT TO SCALE

Schematic Diagram of In Situ Groundwater Treatment System

The SITE Program assesses but does not approve or endorse technologies.

droplets inside the well casing. Countercurrent air flow strips additional chlorinated VOCs from the water, similar to standard air stripping systems.

Water is sparged as it collects in the upper well, at the water table. A packer separates the upper well from the lower, forcing water to recharge at the water table. Fine bubble aerators transfer large volumes of air through the water, aerating and stripping off remaining VOCs. Throughout this process, a slight vacuum in the upper well draws stripped VOCs to the PCO unit.

Water from the lower portion of the aquifer flows into the well to replace the air-lifted water, causing drawdown. Thus, water is circulated from the lower portion of the aquifer into the well and then back to the upper portion of the aquifer, establishing a recirculating treatment zone. Multiple treatment stages are used to achieve maximum cleanup efficiencies. The system is designed to remove chlorinated VOCs below maximum contaminant levels in the first pass. Therefore, water reintroduced to the upper aquifer should not degrade water quality.

WASTE APPLICABILITY:

The in situ groundwater treatment system is designed to remove VOCs, including trichloroethene, benzene, and chloroform, from groundwater.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1993. The demonstration is on hold pending selection of a new location at Site 2 of March Air Force Base, California.

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The SITE Program assesses but does not approve or endorse technologies.

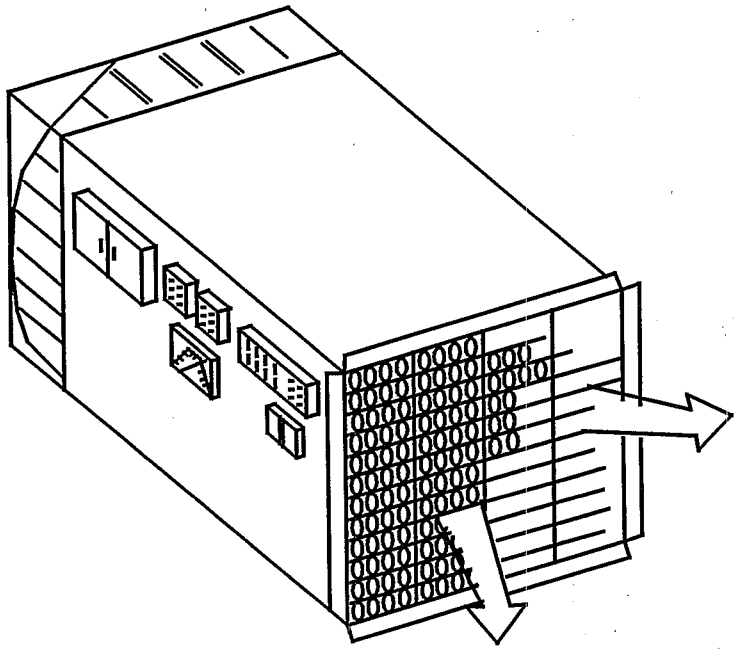
MATRIX PHOTOCATALYTIC INC.
(formerly NUTECH ENVIRONMENTAL)
(Photocatalytic Water Treatment)

TECHNOLOGY DESCRIPTION:

The Matrix Photocatalytic Inc. (Matrix), formerly Nutech Environmental, photocatalytic oxidation system, shown in the photograph below, efficiently removes and destroys dissolved organic contaminants from water in a continuous flow process at ambient temperatures. When excited by light, the titanium dioxide (TiO_2) semiconductor catalyst generates hydroxyl radicals that oxidatively break the carbon bonds of hazardous organic compounds. The catalyst also generates electron holes, which are powerful reducing species.

The Matrix system, when given sufficient time, converts organics such as polychlorinated biphenyls (PCB); phenols; benzene, toluene, ethylbenzene, and xylene (BTEX); and others to carbon dioxide and water. Typically, efficient destruction occurs between 30 seconds and 2 minutes actual exposure time. Total organic carbon removal takes longer, depending on the other organic molecules and their molecular weights.

The Matrix system was initially designed to destroy organic pollutants or to remove total organic carbon in drinking water, groundwater, and plant process water. The Matrix system also destroys organic pollutants such as PCBs, polychlorinated dibenzodioxins, polychlorinated dibenzofurans, chlorinated alkenes, chlorinated phenols, chlorinated benzenes, alcohols, ketones,



10-gpm TiO_2 Photocatalytic System Treating BTEX in Water

The SITE Program assesses but does not approve or endorse technologies.

aldehydes, and amines. Inorganic pollutants such as cyanide, sulphite, and nitrite ions can be oxidized to cyanate ion, sulphate ion, and nitrate ion, respectively.

WASTE APPLICABILITY:

The Matrix system can treat a wide range of concentrations of organic pollutants in industrial wastewater, and can be applied to the ultrapure water industry and the drinking water industry. The Matrix system can also remediate groundwater.

STATUS:

The Matrix system was accepted into the SITE Emerging Technology Program in May 1991. Based on results from the Emerging Technology Program, the technology was invited to participate in the Demonstration Program. A demonstration site at DOE's Oak Ridge, Tennessee complex has been established.

Technological advances since that time include the following:

- The Matrix system has treated effluents with contaminants, such as solvents and alcohols, as high as 30,000 parts per million (ppm), and has achieved effluent qualities as low as 5 parts per trillion.
- Performance has quadrupled over 1992 standards.
- Numerous extended field trials have been conducted on raw effluent contaminated with a variety of organics, mainly BTEX, trichloroethene, and methyl tertiary butyl ether. Average treatment time was 60 seconds at a direct operating cost of $1 to $2 per 1,000 gallons.
- The technology was used for 6 months in a sustained field operation on groundwater contaminated with 1 ppm ferrous ion (Fe^{+2}) with no appreciable iron fouling.
- Modular systems have been developed for high flow rates with capacity increments of 5 gallons per minute. Capital costs are highly competitive with ultraviolet/hydrogen peroxide technologies while operating costs are usually one-fifth to one-third less.
- Matrix has successfully designed and field tested support systems for unattended operation.
- The Matrix system has successfully treated highly turbid effluents and dyes in plant operations.

The research under the Emerging Technology Program was completed in September 1993. Two peer-reviewed journal articles are available through National Technical Information Services (NTIS), document Nos. PB93-222883 and PB93-130184. For a comprehensive bibliography of TiO_2 research, please obtain NTIS document No. DE94-006906.

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The SITE Program assesses but does not approve or endorse technologies.

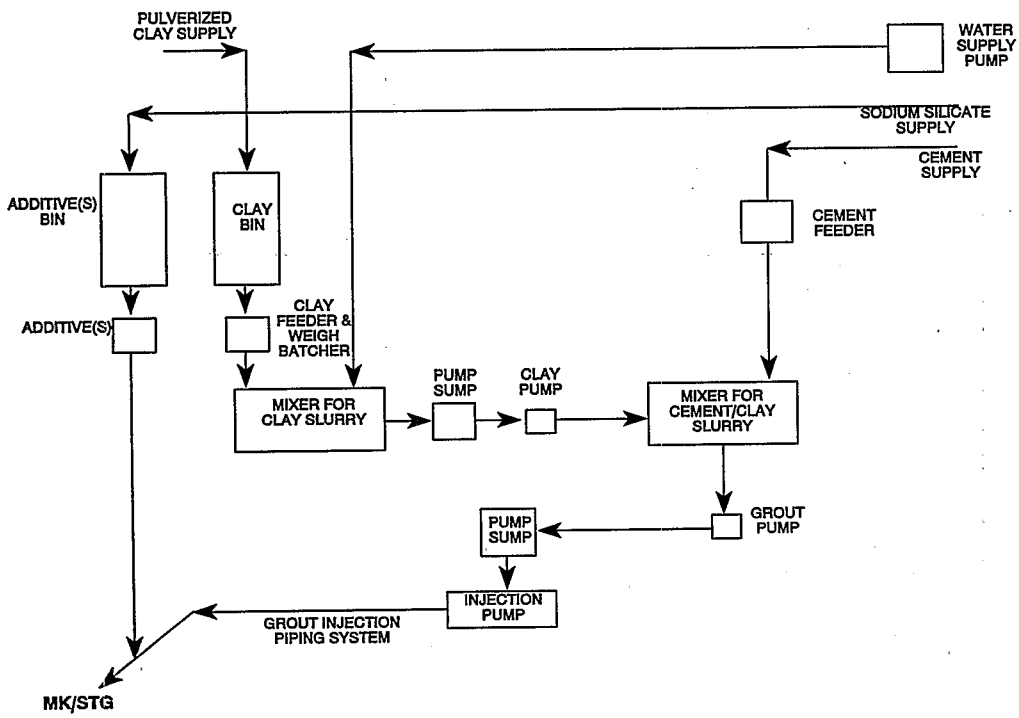
MORRISON KNUDSEN CORPORATION/ SPETSTAMPONAZHGEOLOGIA ENTERPRISES (STG)
(High Clay Grouting Technology)

TECHNOLOGY DESCRIPTION:

Morrison Knudsen Corporation (MK) is working under a joint venture agreement with Spetstamponazhgeologia Enterprises (STG) of Ukraine to demonstrate the effectiveness of a clay-based grouting technology. This technology uses clay slurries as a base for grout solutions which are injected into fissures, fractures, or intergranular spaces in rock to inhibit or eliminate groundwater flow in these pathways. The clay slurries may also be used as a base for slurry wall construction.

The MK/STG clay-based grouting technology is an integrated method involving three primary phases: obtaining detailed information about site characteristics; developing a site-specific grout formulation; and placing the grout.

The first phase, site characterization, includes obtaining geophysical, geochemical, mineralogical, and hydrogeological information about the target area. The second phase, grout formulation, follows the characterization/investigation phase. The overall properties of clay-based grouts depend on the physical and mechanical properties of the clay, cement, and chemical reagents added. Formulated clay-based grouts are viscoplastic systems comprised primarily of structure-forming cement and clay mineral mortar. The clay is a kaolin/illite obtained from a local source, and the other additives are chemically analyzed and laboratory-tested to determine their reactions and suitabilities. Throughout the stabilization period, the clay-based grout retains its plasticity and does not crystallize, unlike cement-based grouts.



Schematic Diagram of the High Clay Grouting Technology

The SITE Program assesses but does not approve or endorse technologies.

The third phase is grout placement. The boreholes drilled during the geological/hydrological study may be used for grout placement, along with any additional required holes. A quality assurance program ensures that placement and project objectives are met.

WASTE APPLICABILITY:

This technology is suitable for providing a barrier to groundwater flows contaminated with both heavy metals and organics, and can be formulated to withstand detrimental conditions such as low pH. The technology will be demonstrated on a stream and associated groundwater flowing into a disused mine site that produces acid mine drainage. Other potential applications include liquid effluent control from landfills, containment of chemically-or-radioactively contaminated groundwater, and reduction of brine inflows.

STATUS:

This technology was accepted into the SITE Demonstration Program in winter 1993. It will be evaluated at the abandoned Mike Horse Mine site in Montana in fall 1994.

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The SITE Program assesses but does not approve or endorse technologies.

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION
(Multi-Vendor Bioremediation)

TECHNOLOGY DESCRIPTION:

This project will demonstrate the effectiveness of three similar innovative bioremediation technologies at an inactive hazardous waste site in Sweden, New York. The pilot-scale, multi-vendor treatability demonstration (MVTD) is jointly sponsored by the New York State Department of Environmental Conservation (NYSDEC), the New York State Center for Hazardous Waste Management (NYS Center), and the SITE Program.

The three vendors and technologies that will be demonstrated are:

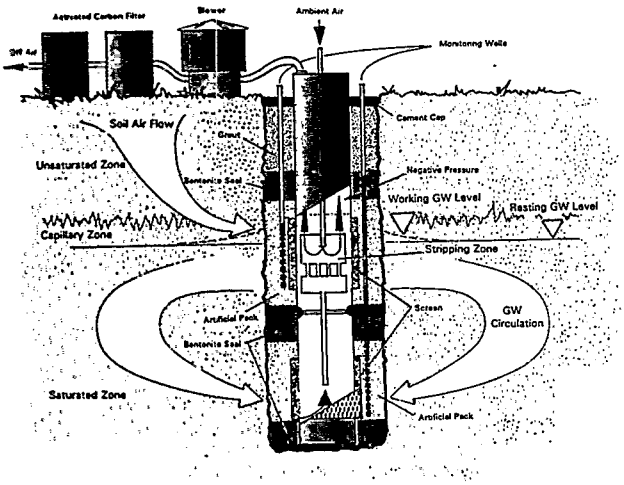
- SBP Technologies, Inc. (SBP), and Environmental Laboratories, Inc., Vacuum-Vaporized Well (UVB) system
- R.E. Wright Associates, Inc., In Situ Field Bioremediation Treatment System
- ENSR Consulting and Engineering and Larson Engineers Ex Situ Biovault

The SBP and Environmental Laboratories, Inc., process consists of a specially adapted groundwater well, a negative pressure stripping reactor, an in situ bioreactor, and an above-ground vapor-phase bioreactor. The process removes volatile contaminants from the soil above the watertable and from groundwater. The contaminants are then treated biologically.

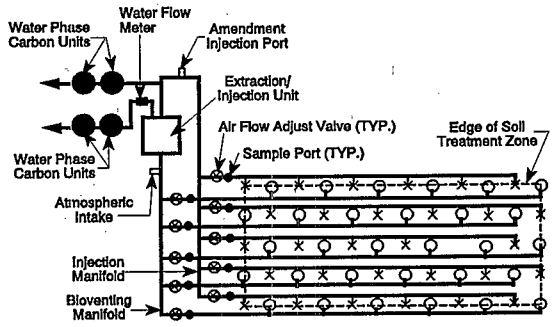
The R.E. Wright Associates, Inc., process uses a bioventing technology where injection and extraction wells allow the developer to regulate oxygen and nutrient levels to stimulate the native bacteria in the soil into biodegrading the contaminants of concern.

ENSR Consulting and Engineering and Larson Engineers process is based on construction of two identical biovaults. Contaminated soils are placed in each biovault where nutrient, moisture, and oxygen levels can be controlled. The first biovault is operated under aerobic conditions. The second biovault is operated back and forth between aerobic and anaerobic conditions.

The objectives of the MVTD are to generate field data to simultaneously compare three biological processes, and evaluate the perfor-



Vacuum-Vaporized Well (UVB) System
Standard Circulation



Schematic Diagram of the In Situ
Field Bioremediation Treatment System

The SITE Program assesses but does not approve or endorse technologies.

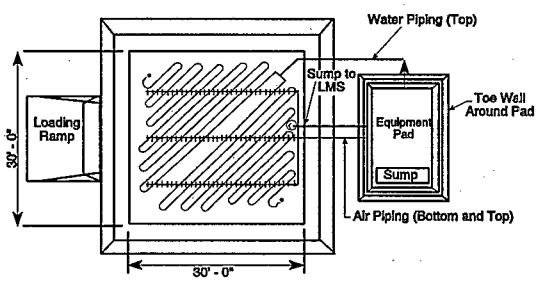
mance of each biological approach in meeting the cleanup goals.

WASTE APPLICABILITY:

All three technologies can treat soil contaminated with volatile organic compounds.

STATUS:

The MVTD is occurring at the Sweden 3-Chapman site in Sweden, New York. The demonstration is coinciding with the on-going remediation at the site, where approximately 2,500 drums of hazardous waste and contaminated soil have already been removed. Field work began in July 1994 and is expected to be completed by December 1994. Final reports from the demonstration will be available in July 1995.



Schematic Diagram of the
Ex Situ Biovault System

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The SITE Program assesses but does not approve or endorse technologies.

NORTH AMERICAN TECHNOLOGIES GROUP, INC.
(BioTreat™ System)

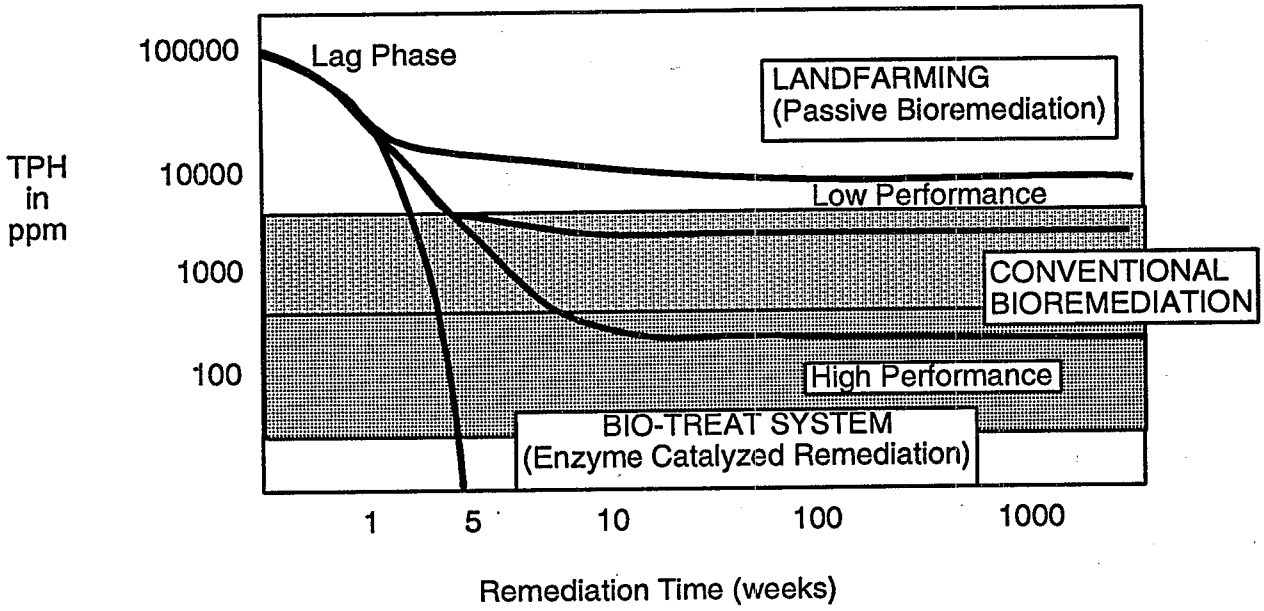
TECHNOLOGY DESCRIPTION:

The proprietary BioTreat™ System features a series of multicomponent, functional, and biochemical systems that provide for customized treatment of organic contaminants in a wide variety of host environments. Each system consists of a contaminant-specific microbial ecosystem. Treatment bacteria are dispersed in a custom-blended nutrient mixture which is delivered by an enhanced polyphasic colloidal emulsifier when conditions require.

The BioTreat™ System is designed to accelerate the naturally-occurring biodegradation process. It can be used in fixed biocells or applied directly as an in situ treatment method. The system overcomes traditional bioremedial limitations by using indigenous bacteria with specially-selected enzymes.

The enzymes first break down the physical and chemical bonds between clay lenses by neutralizing inherent electrical charges. This step drastically improves permeability and releases trapped contaminants. Second, the enzymes chemically bind to the hydrocarbons, resulting in enzyme-catalyzed metabolic remediation that significantly reduces treatment times. In most projects completed to date, contamination was reduced to below action levels within 30 days. The figure below illustrates remediation times for the BioTreat™ System compared to landfarming and conventional bioremediation techniques.

The BioTreat™ System is designed to destroy on site contaminants through biological oxidation. Four proprietary bioremedial agents assist biotreatment; each of these agents is specific to individual soil and contaminant characteristics



BioTreat™ System Remediation Times

The SITE Program assesses but does not approve or endorse technologies.

such as size, depth, density, and concentration. In each case, indigenous bacteria are cultivated for remediation.

WASTE APPLICABILITY:

The BioTreat™ System can treat most organic contaminants in a variety of media, including sludges, soils and mixed media. Soils with high clay content traditionally represent the most difficult treatment matrix; however, the BioTreat™ System has proved most effective in clays. The BioTreat™ System can remediate hydrocarbons such as gasoline, jet fuel, diesel fuel, motor oil, crude oil, polynuclear aromatic hydrocarbons, and single-ring aromatic compounds such as benzene, toluene, xylene, and ethylbenzene. Other compounds amenable to treatment include methyl isobutyl ketone, trichloroethene, pentachlorophenol, and creosotes. Treatment of chlorinated compounds requires an additional step in the bioremediation process, increasing the total treatment time by 60 or more days.

STATUS:

This technology was accepted into the SITE Demonstration Program in early 1993. EPA is seeking a suitable site for the demonstration.

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The SITE Program assesses but does not approve or endorse technologies.

PINTAIL SYSTEMS INCORPORATED
(Spent Ore Bioremediation Process)

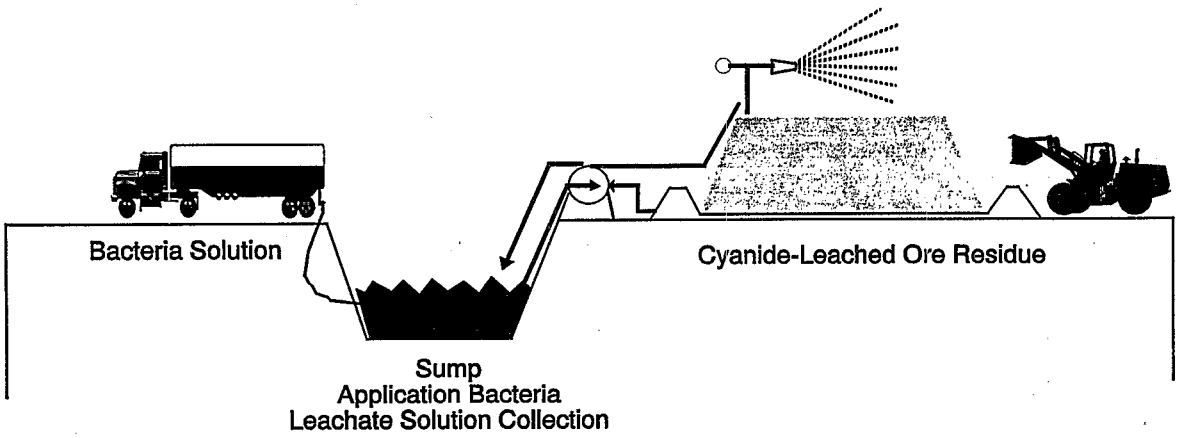
TECHNOLOGY DESCRIPTION:

This technology uses microbial detoxification of cyanide in heap leach processes to reduce cyanide levels in spent ore and process solutions. The biotreatment populations of natural soil bacteria are grown to elevated concentrations and applied to spent ore in a drip or spray irrigation. Process solutions are treated with bacteria concentrates in continuous or batch applications. This method may also enhance metal remineralization, reducing acid rock drainage and enhancing precious metal recovery to offset treatment costs.

Biotreatment of cyanide in spent ore and ore processing solutions is developed by identifying some of the bacteria that will grow in the waste source, and that use the cyanide for normal cell building reactions. Native isolates are ideally adapted to the spent ore environment, the available nutrient pool, and potential toxic components of the heap environment. The cyanide-detoxifying bacteria are typically a small fraction of the overall population of cyanide-tolerant species.

For this reason, native bacteria isolates are extracted from the ore and tested for cyanide detoxification potential as individual species. Any natural detoxification potentials demonstrated in flask cyanide decomposition tests are preserved and submitted for bioaugmentation. Bioaugmentation of the cyanide detoxification population eliminates non-working species of bacteria and enhances the natural detoxification potential by growth in waste infusions and chemically defined media. Pintail Systems Incorporated (PSI) maintains a bacterial library of some 2,5000 strains of microorganisms and a database of their characteristics.

The working population of treatment bacteria is grown in spent ore infusion broths and process solutions to adapt to field operating conditions. The cyanide in the spent ore serves as the primary carbon and/or nitrogen source for bacteria nutrition. Other required trace nutrients are provided in the chemically defined broths. The bacterial consortium is then tested on spent ore in a 6 inch by 10 foot column in the field or in the laboratory. By mimicking leach pile condi-



Spent Ore Bioremediation Process

The SITE Program assesses but does not approve or endorse technologies.

tions, detoxification rates, process completion, and effluent quality can be verified. Following column tests, a field test may be conducted to verify column results.

The remediation of spent ore is accomplished by setting up a stage culturing system to establish working populations of cyanide-degrading bacteria at the mine site. Bacteria solutions are then applied directly to the heap using the same system originally designed to deliver cyanide solutions to the heap leach pads (see figure on previous page). Cyanide concentrations and leachable metals are then measured in heap leach solutions. This method of cyanide degradation in spent ore leach pads has the advantage of treating the cyanide at the source of contamination, the leach pad, resulting in a much faster rate of cyanide degradation than methods which treat only rinse solutions from the pad. In addition to cyanide degradation, biological treatment of heap leach pads has also shown a significant biomineralization and reduction of leachable metals in heap leachate solutions.

WASTE APPLICABILITY:

The PSI biotreatment process is applicable to the treatment of spent ore heaps, waste rock dumps, mine tailings, and process water from gold and silver mining operations.

STATUS:

This technology was accepted into the SITE Demonstration Program in May 1994. PSI has completed two full-scale cyanide detoxification projects. A SITE Demonstration is planned at the Summitville Mine Superfund Site in Colorado for spring 1995.

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The SITE Program assesses but does not approve or endorse technologies.

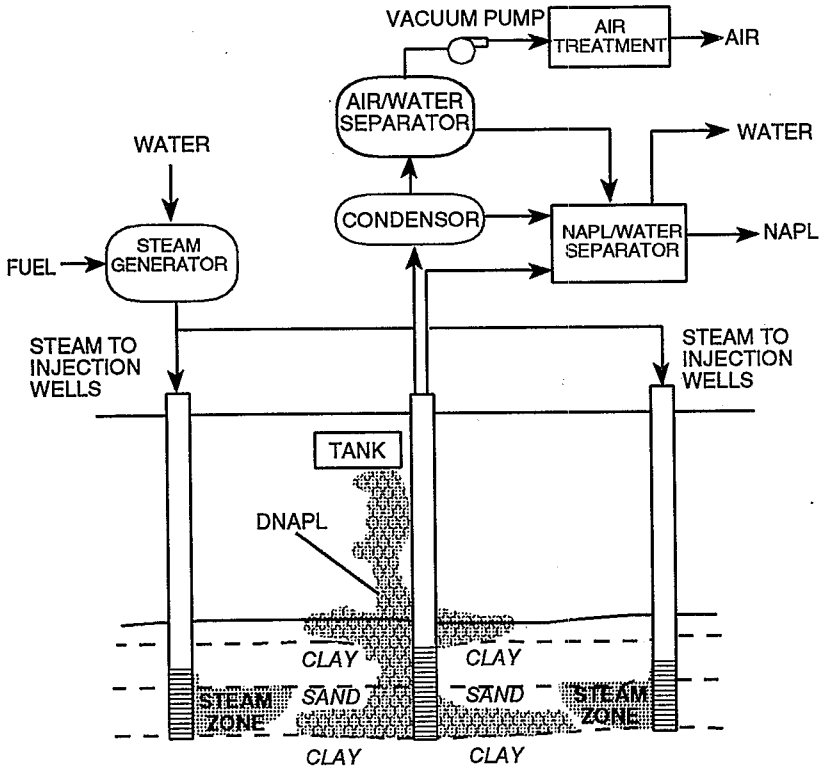
PRAXIS ENVIRONMENTAL TECHNOLOGIES, INC.
(In Situ Thermal Extraction Process)

TECHNOLOGY DESCRIPTION:

The in situ thermal extraction process enhances pump-and-treat and soil vapor extraction processes used to treat volatile organic compounds (VOC) and semivolatile organic compounds (SVOC). Heating the soil with steam injection is an effective and relatively inexpensive technique to raise a target soil volume to a nearly uniform temperature.

As illustrated in the figure below, steam is introduced to the soil through injection wells screened in contaminated zones both above and below the water table. The steam flow sweeps contaminants to extraction wells. Groundwater and liquid contaminants are pumped from the extraction wells; steam, air, and vaporized contaminants are then extracted under vacuum. After the soil is heated by steam injection, the injection wells can introduce additional agents to facilitate the cleanup.

Recovered vapors pass through a condenser. The resulting condensate is combined with pumped liquids for processing in separation equipment. Separated nonaqueous phase liquids (NAPL) can be recycled or disposed of, and the water is treated prior to discharge. The noncondensible gases are directed to a vapor treatment system consisting of 1) oxidation equipment, 2) activated carbon filters, or 3) treated on site in a catalytic destruction process. The in situ thermal extraction process uses conventional injection, extraction and monitoring wells, off-the-shelf piping, steam generators, condensers, heat exchangers, separation equipment, vacuum pumps, and vapor emission control equipment.



In Situ Thermal Extraction Process

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The in situ thermal extraction process removes VOCs and SVOCs from contaminated soils and groundwater. The process primarily treats chlorinated solvents such as trichloroethene (TCE), perchloroethene (PCE), and dichlorobenzene; hydrocarbons such as gasoline, diesel, and jet fuel; and mixtures of these compounds. The process can be applied to rapid cleanup of source areas such as dense NAPL pools below the water table surface, light NAPL pools floating on the water table surface, and NAPL contamination remaining after conventional pumping techniques. Subsurface conditions are amenable to biodegradation of residual contaminants, if necessary, after application of the thermal process. A cap must exist to implement the process near the surface. For dense NAPL compounds in high concentrations, a barrier must be present or created to prevent downward percolation of the NAPL. The process is applicable in less permeable soils using novel delivery systems such as horizontal wells.

STATUS:

This technology was accepted into the SITE Demonstration Program in August 1993. Through a cooperative effort with EPA, Ogden Air Logistics Center Environmental Management Office, and Armstrong Laboratory at Tyndall Air Force Base (AFB), Florida, the demonstration will occur at Hill AFB, Utah in spring 1995.

During the period 1967-1979, unknown quantities of various chlorinated solvents including TCE and PCE were disposed of in two unlined trenches at Hill AFB. These dense NAPL compounds migrated down through the soil and shallow groundwater. The NAPL pooled on top of a natural clay layer about 50 to 60 feet below the surface. The technology demonstration will be performed in this area after the NAPL recovery by conventional pumping diminishes.

For more information about this technology, see the Hughes Environmental Systems, Inc., or the Berkeley Environmental Restoration Center profiles in the Demonstration Program (Completed Projects) section.

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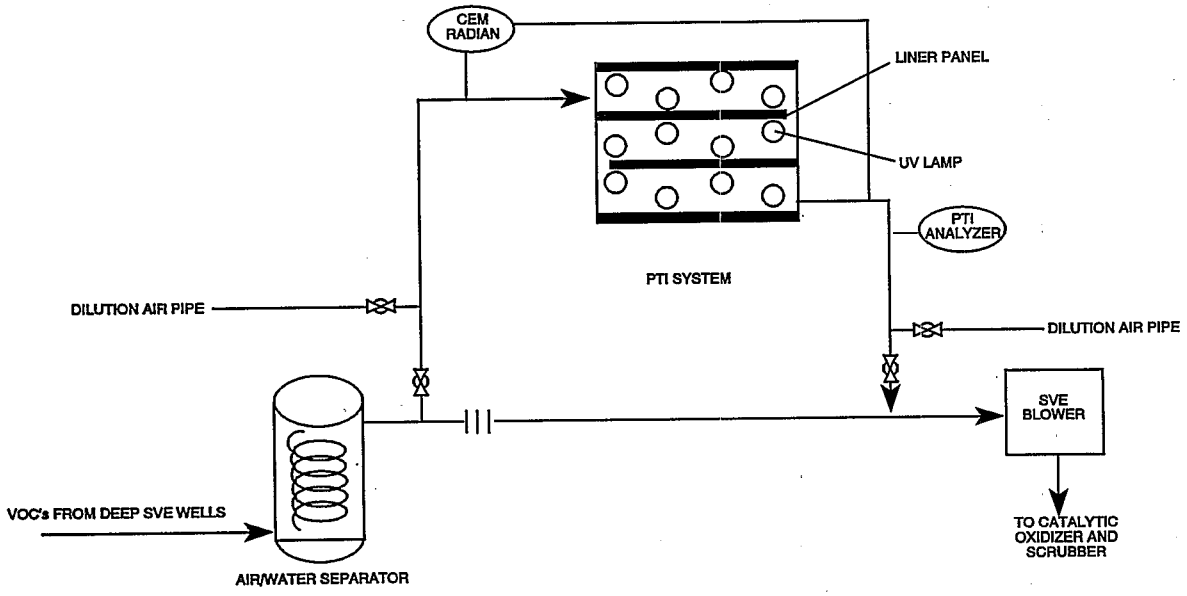
The SITE Program assesses but does not approve or endorse technologies.

PROCESS TECHNOLOGIES, INC.
(Photolytic Destruction for SVE Off-Gases)

TECHNOLOGY DESCRIPTION:

Process Technologies, Inc.'s (PTI), halocarbon and volatile organic compound (VOC) destruction technology photolyzes vapor-phase halogens. The resulting radicals react with cementitious liners to produce a clean air stream. One of the key features and advantages of the technology is its simplicity - there are no moving parts, and its modular design allows for easy scale-up.

During the demonstration, off-gas from an existing soil vapor extraction system (SVE) will be treated by the PTI photolytic process. PTI's equipment operates using low pressure mercury lamps. High intensity UV light at 185 and 254 nanometers generated by the mercury lamps destabilizes and facilitates the breakdown of VOC contamination in the SVE exhaust gas stream. A proprietary liner material present in the light zone captures and neutralizes the resulting process by-products. Extensive testing has proven that the use of the cementitious liner material prevents the formation of undesirable species, such as chlorine, phosgene, and hydrochloric acid. This design is unique to PTI's photolytic process. The gaseous products exiting the system include air, water vapor, and carbon dioxide. The liners are replaced as needed and PTI claims that the cementitious material can be recycled as an ingredient in cement or disposed of as nonhazardous waste, regulations permitting.



Simplified Schematic Process Flow Diagram
of Photolytic Destruction

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The PTI technology treats air and gases contaminated with VOCs, including chlorinated VOCs, and chlorofluorocarbons.

STATUS:

The PTI technology was accepted into the SITE Demonstration Program in summer 1994. The demonstration began in September 1994 at McClellan Air Force Base, in Sacramento, California.

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The SITE Program assesses but does not approve or endorse technologies.

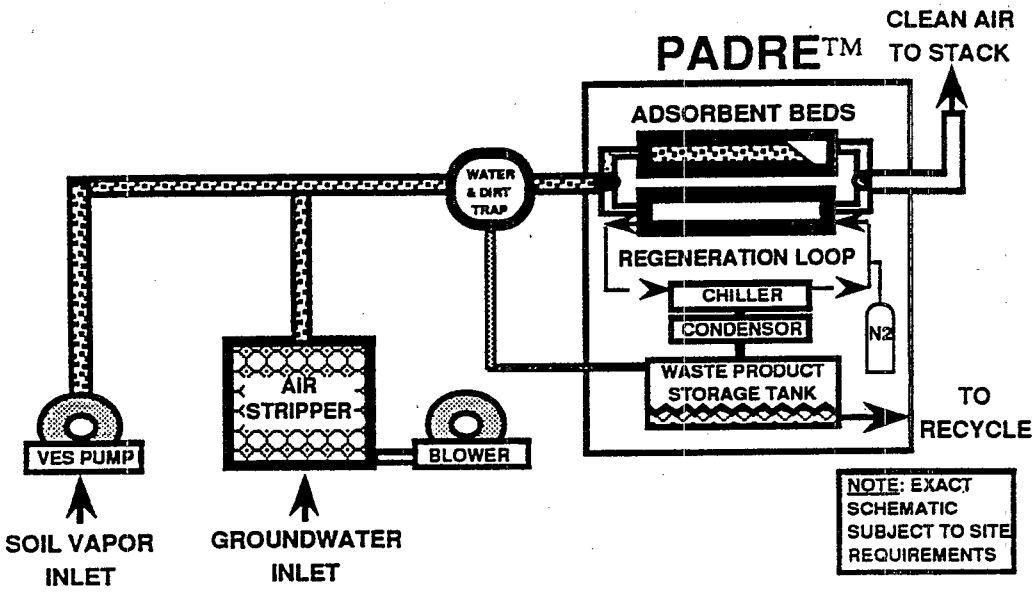
PURUS, INC.
(PurCycle™ Vapor Treatment Process)

TECHNOLOGY DESCRIPTION:

The Purus, Inc. (Purus), PurCycle™ vapor treatment process purifies air streams contaminated with volatile organic compounds (VOC). PurCycle™ works directly from soil extraction wells or from groundwater (or wastewater) air strippers.

The PurCycle™ process traps the contaminants using filter beds that contain a proprietary resin. This regenerative adsorption method involves one on-line treatment bed for influent air, while another bed undergoes a desorption cycle (see figure below). An on-board controller system automatically switches between adsorption and desorption cycles. The desorption cycle uses a combination of temperature, pressure, and purge gas (N_2) to desorb VOCs trapped in the adsorbent bed. The contaminants are removed, condensed, and transferred as a liquid to a storage tank. Thus, the recovered material can be easily reclaimed.

Historically, activated carbon has been the principal medium for separating organic compounds from an air stream. However, because the carbon beds are difficult to regenerate on site, most treatment technologies use a passive carbon system that requires hauling the spent carbon off site for disposal or treatment. Another problem with activated carbon is decreased treatment efficiency resulting from moisture in the waste stream. Moisture in



PurCycle™ Vapor Treatment Process

The SITE Program assesses but does not approve or endorse technologies.

humid contaminated air dramatically reduces the carbon's ability to adsorb organic contaminants; treatment efficiency declines to 30 percent of original efficiency as the relative humidity (RH) exceeds 75 percent.

Adsorbent beds used in the PurCycle™ process have been recycled on a test stand more than 1,000 times with no measurable loss of adsorption capacity. In addition, the PurCycle™ resin has a relatively high tolerance for water vapor, allowing efficient treatment of air streams with an RH greater than 90 percent. These two capabilities make on-site treatment of VOCs possible with substantially lower operating costs.

WASTE APPLICABILITY:

The PurCycle™ vapor treatment process controls VOC emissions at site remediation projects, industrial wastewater facilities, and industrial air processing sites. Site remediation usually involves vacuum extraction of solvents or fuels from soils, as well as the pumping and treatment of groundwater by air stripping. The PurCycle™ process has also treated industrial waste containing solvents using an emission-free, closed-loop air stripping process. For the Demonstration Program, the PurCycle™ vapor treatment process will simultaneously treat vapors from soil vacuum extraction wells and a groundwater air stripper.

STATUS:

Purus, Inc., has over 18 PurCycle™ systems in the field for various applications. Under the SITE demonstration, operating data will be collected from a combined, closed loop, air stripper/soil vacuum extractor system. A suitable demonstration site is being selected.

FOR FURTHER INFORMATION:

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The SITE Program assesses but does not approve or endorse technologies.

REMEDIATION TECHNOLOGIES, INC.
(Liquid and Solids Biological Treatment)

TECHNOLOGY DESCRIPTION:

Liquid and solids biological treatment (LST) is a process that remediates soils and sludges contaminated with biodegradable organics (see figure below). The process is similar to activated sludge treatment of municipal and industrial wastewaters, but it treats suspended solids concentrations greater than 20 percent. First, an aqueous slurry of the waste material is prepared, and environmental conditions such as nutrient concentrations, temperature, and pH are optimized for biodegradation. The slurry is then mixed and aerated for a sufficient time to degrade the target waste constituents.

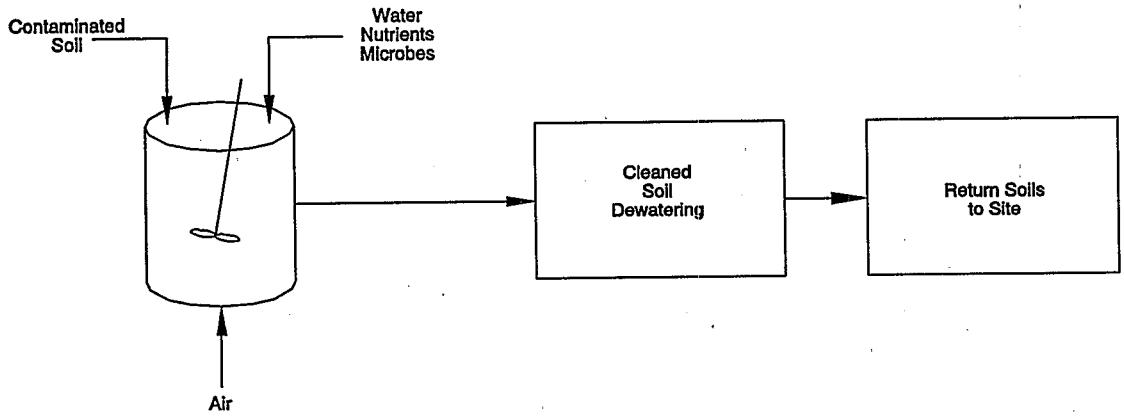
Several physical process configurations are possible depending on site- and waste-specific conditions. Waste can be treated continuously or in batches in impoundment-based reactors. This configuration is sometimes the only practical option for very large projects (greater than 10,000 cubic yards). Alternatively, tank-based systems may be constructed.

Constituent losses due to volatilization must be controlled during LST operations. The potential for emissions is greatest in batch treatment systems and lowest in continuously stirred tank reactor systems, particularly those with long residence times. Technologies such as carbon adsorption and biofiltration can control emissions.

LST may require pre- and posttreatment operations. However, in situ applications that store treated sludge residues do not require multiple unit operations.

Overall bioremediation in a hybrid system consisting of LST and land treatment systems can provide an alternative to landfilling treated solids. This combination rapidly degrades volatile constituents in a contained system, rendering the waste suitable for landfilling.

Remediation Technologies, Inc. (ReTeC), has constructed a mobile LST pilot system for field



Liquid and Solids Biological Treatment

The SITE Program assesses but does not approve or endorse technologies.

demonstrations. The system consists of two reactors, two 2,000-gallon holding tanks, and associated process equipment. The reactors are aerated using coarse bubble diffusers and mixed using axial flow turbine mixers. The reactors can operate separately, or as batch or continuous systems. Oxygen and pH are continuously monitored and recorded. Additional features include antifoaming and temperature control systems.

WASTE APPLICABILITY:

The technology treats sludges, sediments, and soils containing biodegradable organic materials. To date, the process has mainly treated sludges containing petroleum and wood preservative organics such as creosote and pentachlorophenol (PCP). LST has successfully treated polynuclear aromatic hydrocarbons, PCP, and a broad range of petroleum hydrocarbons in the laboratory and the field.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1987. A 50,000 gallon slurry bioreactor system will be constructed next spring at Utica, New York to treat sediments from the barge harbor contaminated with polycyclic aromatic hydrocarbons from municipal town gas wastes.

ReTeC has applied the technology in the field over a dozen times to treat wood preservative sludges with impoundment-type LST systems. In addition, LST has treated petroleum refinery impoundment sludges in two field-based pilot demonstrations and several laboratory treatability studies.

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The SITE Program assesses but does not approve or endorse technologies.

RISK REDUCTION ENGINEERING LABORATORY
(Bioventing)

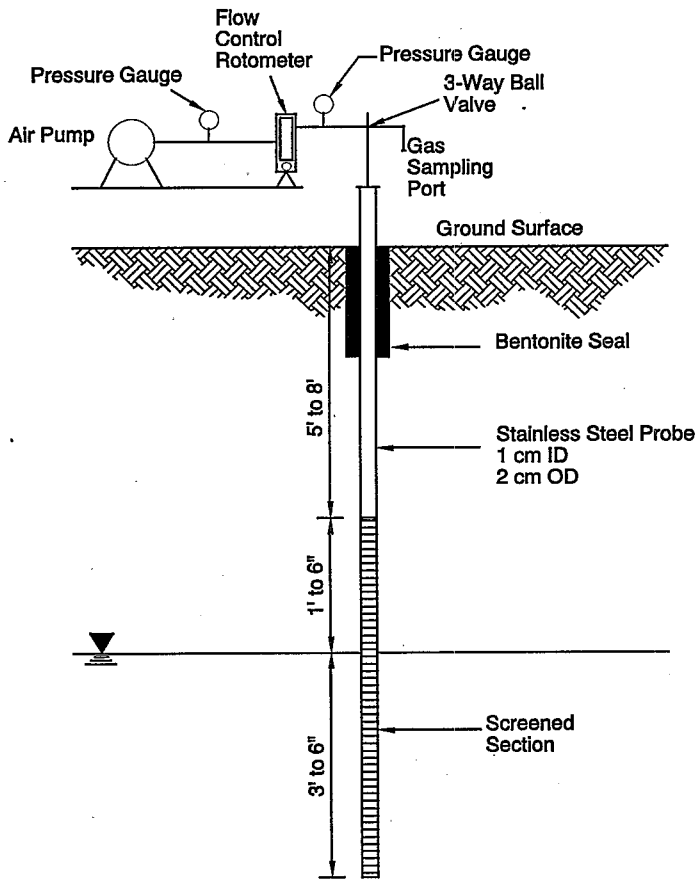
TECHNOLOGY DESCRIPTION:

Lack of oxygen in contaminated soil often limits aerobic microbial growth. The bioventing biological system treats contaminated soil in situ by injecting atmospheric air. This air provides a continuous oxygen source, which enhances the growth of microorganisms naturally present in the soil. Additional additives, such as ozone or nutrients, may also be added to stimulate microbial growth.

Bioventing technology uses an air pump attached to one of a series of air injection probes (see figure below). The air pump operates at extremely low pressures, providing inflow of oxygen without significantly volatilizing soil contaminants. The treatment capacity depends on the number of injection probes, the size of the air pump, and site characteristics such as soil porosity.

WASTE APPLICABILITY:

Bioventing is typically used to treat soil contaminated by industrial processes, and can treat any contamination subject to aerobic microbial degradation. Bioventing treats contaminants and



Bioventing System

The SITE Program assesses but does not approve or endorse technologies.

combinations of contaminants with varying degrees of success. The SITE Demonstration Program is testing bioventing's effectiveness at degrading polynuclear aromatic hydrocarbons.

STATUS:

This technology was accepted into the SITE Demonstration Program in July 1991. The demonstration of this process began in November 1992 at the Reilly Tar site in St. Louis Park, Minnesota. Preliminary findings after 27 months of bioventing indicated higher than predicted microbial respiration rates. The project will be completed in November 1995.

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The SITE Program assesses but does not approve or endorse technologies.

RKK, Ltd.
(CRYOCELL®)

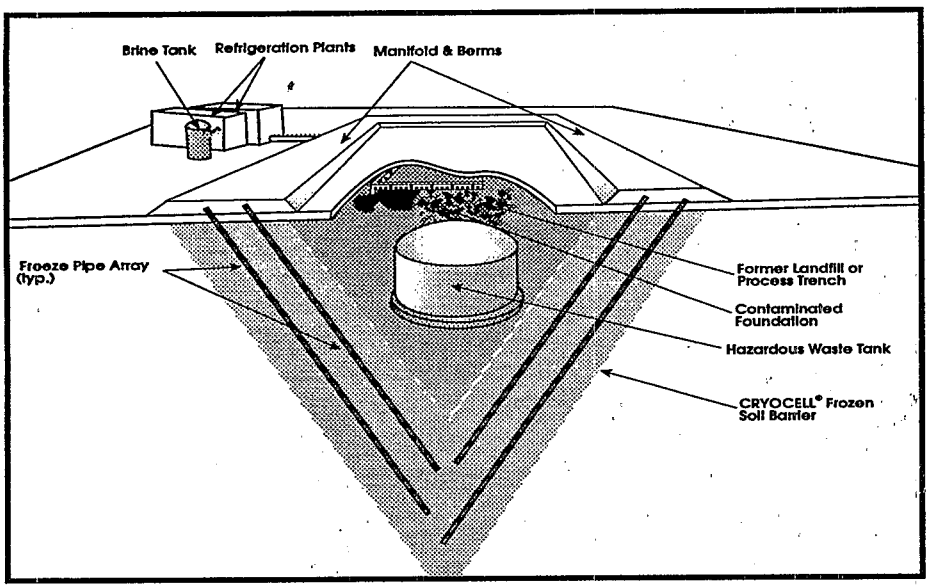
TECHNOLOGY DESCRIPTION:

CRYOCELL® is a frozen soil barrier that completely contains waste migration to the soil or isolates a contaminated area during an in situ remediation program. The CRYOCELL® design involves installing freeze pipes in an array outside and beneath the contaminated zone to completely surround the waste source or groundwater plume. Standard well drilling equipment is used to drill or drive the freeze pipes into place. Once installed, the array of pipes is connected to a freeze plant by a distributive manifold. The pipes carry a cooled brine in a completely closed system, which freezes the entire inner volume between the pipes, and the adjacent earth to the outside of the row(s) of pipes.

The barrier thickness and temperature may be varied to suit site conditions. RKK, Ltd. (RKK), reports that barriers can be established at depths of 1,000 feet or more and may vary in thickness from 15 to 50 feet.

CRYOCELL® engineering is site-specific and considers many factors, including waste type, topography, soil condition, thermal conductivity, and groundwater movement. A computer program incorporates all site characteristics into a three-dimensional model that planners use to design and estimate costs of CRYOCELL® costs for a specific site.

A thick ice barrier offers a number of advantages for confining hazardous waste. The ice does not degrade or weaken over time and is reparable in situ. If ground movement fractures the barrier, the fissures can be filled and resealed quickly. Maintenance costs are extremely low, allowing continued use for extended periods. In addition, the frozen barrier is environmentally benign. When the site is decontaminated, the ice is allowed to melt and the pipes are removed. The technique is an alternative to conventional containment systems using steel, concrete, slurry walls, or grout curtains. The figure below provides an illustration of a typical containment system.



Schematic Diagram of CRYOCELL®

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

RKK reports that CRYOCELL® can provide subsurface containment for a variety of sites and wastes, including underground tanks; nuclear waste sites; hazardous or mixed-waste sites; plume control; burial trenches, pits, and ponds; in situ waste treatment areas; chemically-contaminated sites; and spent fuel storage ponds. CRYOCELL® is designed to contain all known biological, chemical, or radioactive contaminants. Design criteria (for example, barrier thickness and temperature) are site specific and depend upon factors such as type of waste involved, overall site hydrogeology, soil moisture content, and soil types. Frozen soil barriers are adaptable to any geometry; drilling technology presents the only constraint.

RKK reports that the technology can isolate sensitive areas within large active operations (for example, sites within chemical and nuclear facilities), smaller raw material and waste management unites (for example, tank farms, landfills, and waste treatment lagoons), and former or operational chemically contaminated sites, such as chemical plants, refineries, and substations. The technology can also contain new waste storage areas and subsurface contamination during a remediation project. The technology can also provide a redundant barrier for other cutoff containment processes, and reduces flow of groundwater into a contaminated zone.

Contaminants are contained in situ, with native soils serving as the containment medium. Thick ice barriers are impervious to chemical attack and are virtually impermeable at subzero temperatures. In addition, ice barriers have great inertia, so they can remain frozen for as long as two years without refrigeration. CRYOCELL® is economically favorable for intermediate and long term containment at large sites, and maintenance costs are extremely low. CRYOCELL® generates no waste streams or residues.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1994. EPA is seeking a suitable site for this demonstration.

RKK technologies are being considered by the U.S. Department of Energy (DOE) for many hazardous waste sites including containment of Hanford's single-shell tanks, the nation's most costly waste site. RKK receives academic, technical, and scientific support through a cooperative and licensing agreement with the University of Washington. RKK has an agreement with Scientific Ecology Group, Inc. (SEG), a subsidiary of the Westinghouse Electric Corporation. This agreement encompasses DOE weapons complex sites.

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The SITE Program assesses but does not approve or endorse technologies.

SEPARATION AND RECOVERY SYSTEMS, INC.
(SAREX Chemical Fixation Process)

TECHNOLOGY DESCRIPTION:

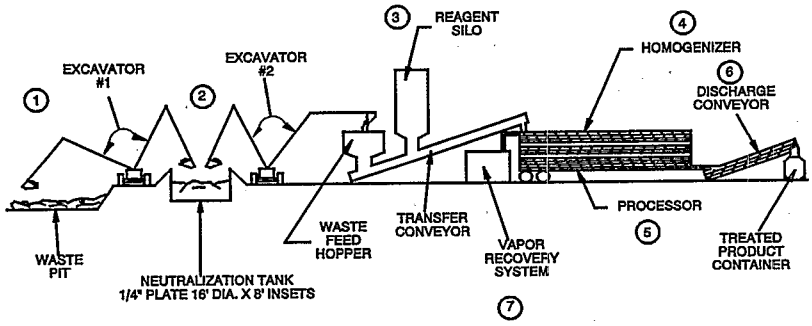
The SAREX chemical fixation process (CFP), developed by Separation and Recovery Systems, Inc. (SRS), is a thermal and chemical reactive (fixation) process that removes volatile organic compounds (VOC) and selected semivolatile organic compounds (SVOC), and stabilizes the remaining organic and inorganic constituents in sludges or soils (see figure below). The SAREX CFP uses specially-prepared lime and proprietary, nontoxic chemicals (a reagent blend) mixed proportionally to catalyze and control the reactions. The treated product displays chemical properties which conform to EPA standards for resource recovery and site restoration. The product also exhibits high structural integrity, with a fine, granular, soil-like consistency, of limited solubility. The treated product is free-flowing until compacted (50 to 80 pounds per square inch), isolating the remaining constituents from environmental influences. The treated product can be easily backfilled and compacted on site.

Depending on the characteristics of the waste material, the waste may be covered with a liquid neutralizing reagent that initiates the chemical reactions and helps prevent vapor emissions. If required, the waste material may be moved to the neutralization (blending) tank, where a make-up reagent slurry is added, depending on material characteristics. The waste is then placed in the feed hopper.

The reagent is measured and placed on the transfer conveyor so that the reagent and waste mixture would advance to the single-screw homogenizer, where the waste components are thoroughly blended to a uniform consistency. The reagent blend reacts exothermically with the hazardous constituents to begin removing the lighter organics. The process, now about 70 percent complete, continues in the multi-screw, jacketed, noncontacting processor for curing (a predetermined curing time allows reactions to occur within a controlled environment).

In the processor, the mixture can be thermally processed at a high temperature to complete the process and meet stringent cleanup standards. The processed material exits the processor onto a conveyor for discharge into sealed storage containers.

Contaminant loss into the air during processing is eliminated by use of a specially designed



NOTES:
1. EXCAVATION/NEUTRALIZATION/VAPOR CONTROL
2. PRE-PROCESS BLENDING/NEUTRALIZATION
3. WASTE FEED TO PROCESSOR
4. HOMOGENIZING
5. PROCESSING
6. DISCHARGE CONVEYOR
7. VAPOR RECOVERY SYSTEM (vrs)

SAREX Chemical Fixation Process

The SITE Program assesses but does not approve or endorse technologies.

SAREX vapor recovery system. Dust particles can be removed in a baghouse, and vapors are routed through a series of water scrubbers, which cool the vapors (below 120 degrees Fahrenheit [°F]) and remove any condensates. The vapors then pass through two demisters to remove water vapor, and a positive displacement blower to remove additional condensates. If needed, a freon chilling unit (37 °F) cools the remaining vapors, which are sent to a storage tank. The final noncondensible vapor stream is treated using two charcoal vapor packs or a thermal oxidizer before release.

WASTE APPLICABILITY:

The SAREX CFP may be applied to a wide variety of organic and inorganic materials. These materials include sludges that contain high concentrations of hazardous constituents, with no upper limit of oil or organic content. No constituents interfere with the fixation reactions, and water content is not an obstacle, although the exothermic reactions may cause steaming. The following material types can be processed by the SAREX CFP:

- Large crude oil spills
- Refinery sludges
- Hydrocarbon-contaminated soils
- Lube oil acid sludges
- Tars
- Halocarbon-contaminated sludges or soils

In addition, metals are captured within the treated matrix and pass the toxicity characteristic leaching procedure. This is advantageous because most on-site cleanup programs focus on sludge ponds, impoundments, and underlying soils which have received many different types of compounds and debris over several years.

STATUS:

SRS has completed at least five full-scale projects using the SAREX CFP. These projects included stabilizing 2,000- to 20,000- cubic-yard quantities of lubricating oil acid sludges, petroleum hydrocarbon-impacted soils, and oil production wastes.

Additionally, SRS has conducted numerous pilot-scale field demonstrations. In 1987, SRS conducted pilot testing for stabilizing hazardous refining sludges at a Superfund site in Oklahoma. Over 400 cubic yards of sludges were stabilized during these tests. Results were favorable, and a Record of Decision was recently issued for the use of chemical fixation as the remedial technology.

SRS expects to conduct a SITE demonstration in fall 1994 at a Superfund site in New Jersey. This site has numerous sludge lagoons containing elevated levels of organics (principally benzene, toluene, ethylbenzene, and xylene; chlorobenzenes; and polynuclear aromatic hydrocarbons) and heavy metals (lead, zinc, and chromium). SRS has completed bench-scale testing on samples collected from three lagoons. The test results were favorable.

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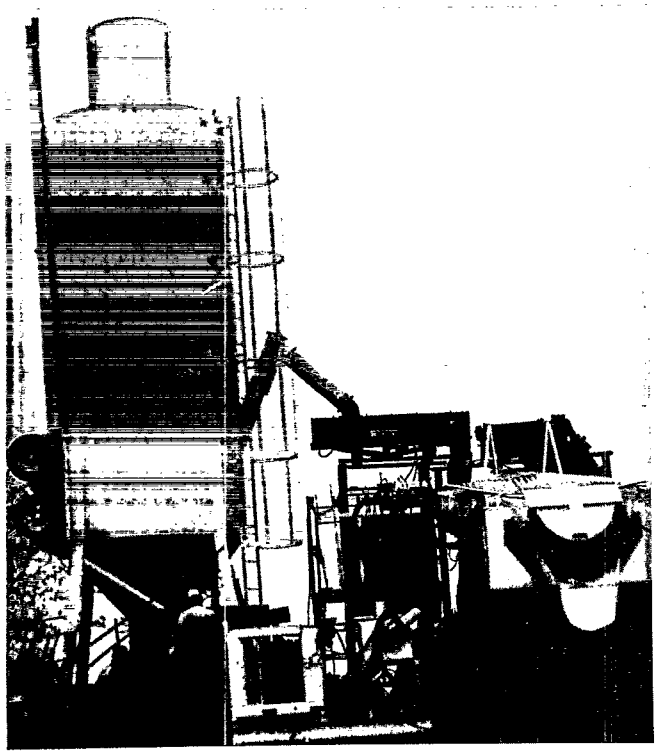
The SITE Program assesses but does not approve or endorse technologies.

SEVENSON ENVIRONMENTAL SERVICES, INC.
(MAECTITE® Chemical Treatment Process)

TECHNOLOGY DESCRIPTION:

The patented MAECTITE® chemical treatment process for lead and other heavy metals utilizes reagents and processing equipment to render soils, waste and other materials nonhazardous for the characteristic definition of toxicity under Resource Conservation and Recovery Act. The MAECTITE® process reduces leachable lead to below treatment standards for listed waste treatment limits required for land-ban regulations (September 19, 1994 40 CFR Parts 268, Final Rule). Lead in treated material complies with leach limits established by EPA as determined by approved methods in SW-846, including, but not limited to toxicity characteristic leaching procedure (TCLP), EP Toxicity test, and the Multiple Extraction Procedure.



500-Ton Per Day MAECTITE® Processing System

Chemical treatment by the MAECTITE® process converts leachable lead into insoluble minerals and mixed mineral forms within the material or waste matrix. MAECTITE® reagents stimulate the nucleation of crystals by chemical bonding to yield mineral compounds in molecular forms. These are resistant to leaching and physical degradation from environmental forces. Durability of traditional monolithic solidification/stabilization process end-products is often measured by geotechnical tests such as wet/dry, freeze/thaw, permeability, and unconfined compressive strength. Since the MAECTITE® process does not use physical binders, is not pozzolanic or siliceous, and does not rely on the formation of metallic hydroxides using hydration mechanisms, these tests are not relevant to MAECTITE® product chemical stability. MAECTITE® does not utilize adsorption, absorption, entrapment, lattice containment, encapsulation, or other physical binding principles for treatment success. Effective treatment is not pH dependent and is a true chemical reaction process where the treated material is altered in structure and properties yielding stable compounds.

The MAECTITE® process uses water as a mixing lubricant. However, the dehydration characteristic of the process liberates water present in waste prior to treatment (absorbed and hydrated forms) to a free state where it can be removed from the waste matrix by evaporation and capillary drying principles. The ability of treated material to readily lose water, the formation of dense mineral crystals, and the restructuring of the material as a result of MAECTITE® treatment (where interstitial space is minimized), all contribute to reduced waste volume and weight.

Ex situ MAECTITE® processing equipment generally utilizes material screening and sizing components, liquid and solid reagent storage delivery subsystems, and a mixing unit such as

The SITE Program assesses but does not approve or endorse technologies.

a pugmill. Equipment is mobile, but can be modified for fixed system operations. In situ MAECTITE® processing equipment is also available with system selection largely dictated by contaminant plume configuration, soil characteristics, and site space limitations.

WASTE APPLICABILITY:

By selecting proper MAECTITE® treatment chemicals from families of reagents, varying their dosage, and applying appropriate material handling procedures, all material matrices historically subjected to the MAECTITE® process have been successfully treated. Materials including soils, sludges, sediments, battery contents including casings, foundry sands, filtercake, furnace slag and matte, debris and construction rubble, carbon dross, wire fluff and chop, shooting range sand with spent projectiles, blasting sand with lead-based paint chips, auto fluff, bird and buck shot, electronic components, glass, fire brick, coatings, and oxide pigments have been rendered nonhazardous. Oversize material can be treated with the process as debris (best demonstrated achievable technology for lead, i.e., chemical treatment), but size reduction often makes processing more efficient. To date, no material has been found resistant to treatment by the MAECTITE® process. Even sludges with free liquids (as determined by the paint filter test) have been treated to TCLP compliance when excess fluids are present.

The range of lead levels effectively treated has not been fully determined; however, soil with total lead as high as 30 percent (weight) with TCLP values over 4,000 milligrams per liter (mg/l) was not problematic. Common lead levels encountered have averaged from 200 milligrams per kilogram (mg/kg) to 6500 mg/kg with TCLP averaging 20 to 400 mg/l. Material geochemistry most often dictates final MAECTITE® treatment designs. Furthermore, correlation-ships between total lead and regulated leachable lead levels are inconsistent, with treatment efforts more strongly related to waste/material geochemical characteristics.

STATUS:

The patented MAECTITE® chemical treatment technology was initially accepted into the SITE Demonstration Program in March 1992. Sevenson Environmental Services, Inc. acquired the MAECTITE® technology in 1993. Combining ex situ and in situ quantities treated, over 250,000 tons of material have been successfully processed. Treatability studies have been conducted on over 50 different materials (including all types of soils) in over 20 states, Canada, Italy, and Mexico. MAECTITE® has been applied at full-scale demonstration and remedial projects in 14 states.

MAECTITE® chemical treatment is a cost-effective technology when compared to traditional offsite options or to other onsite treatment alternatives. With its MAECTITE® process, Sevenson has been formally accepted in the EPA's PQOPS program for the fixation/stabilization of inorganic species.

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The SITE Program assesses but does not approve or endorse technologies.

SIVE Services
(Steam Injection and Vacuum Extraction-Linear Flow [SIVE-LF] Process)

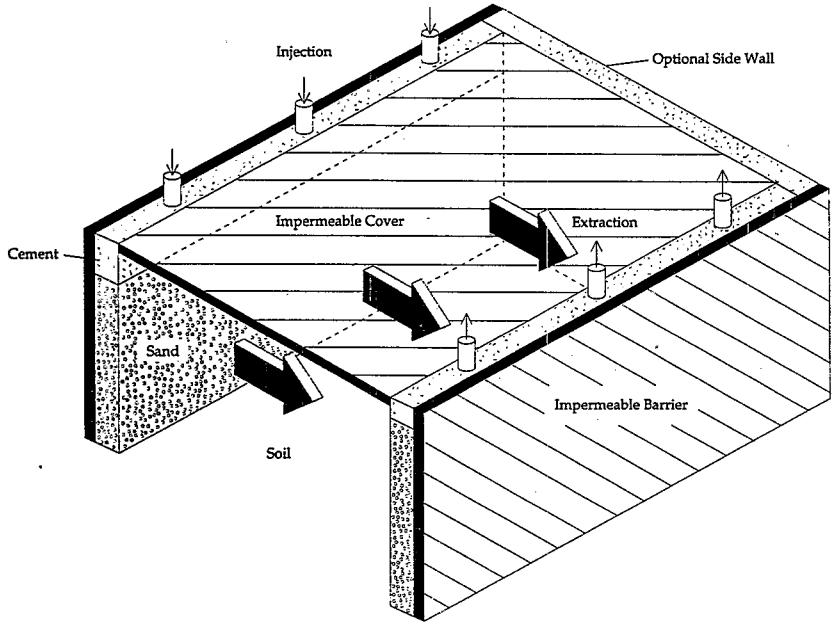
TECHNOLOGY DESCRIPTION:

SIVE-LF is an enhanced steam injection and vacuum extraction method especially designed for in situ treatment of contaminated soil at relatively shallow depths.

Steam is forced to flow horizontally and uniformly from one trench, through the contaminated zone to another trench, where it is then extracted. The large open area of the trench faces allow for high injection and extraction rates, which promote low treatment duration. The trenches also allow for installation of an impermeable barrier, such as a polyethylene liner, against one face of the open trench before the trench is backfilled. Thus, reducing the flow of injected or extracted fluid outside the area of the targeted zones. A surface covering for the treatment area prevents short-circuiting the injected steam to the atmosphere, and prevents atmospheric air from entering the extraction trench.

The injected steam strips contaminants from the soil as it is forced across the contaminated zone. The steam raises the soil temperature, which increases mass transfer and phase change rates, reduces liquid viscosities, and accelerates desorption of contaminants from the soil. The moisture and warmth of the steam also accelerates biodegradation of residual contaminants. As a result, contaminants are extracted or degraded at increased rates, compared to conventional isothermal vapor and liquid extraction systems.

Surface equipment for the SIVE-LF process includes the steam generation and a delivery system and the vacuum extraction system. The steam generation and delivery system consists of standard steam heating equipment, related steam piping, and monitoring equipment. The extraction system is a solvent recovery system that includes a vacuum blower, steam condenser, other cooling equipment, and carbon filters. The condensate requires further treatment or off-site disposal.



Schematic Diagram of the SIVE-LF Process

The SITE Program assesses but does not approve or endorse technologies.

The reliability of the equipment and automatic controls allows the SIVE-LF process to operate without constant direct supervision.

WASTE APPLICABILITY:

The SIVE-LF process is designed to treat soils contaminated with semivolatile and volatile organic compounds to depths of 30 feet. Because highly volatile contaminants are readily air-stripped without the added effects of steam, the steam-stripping effect will be greatest on the heavier, less volatile contaminants. Soils with contaminant concentrations as low as 100 parts per million can be effectively stripped. SIVE-LF can also remove second phase liquids, such as fuels and oils, from the tops of underground water tables.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1994. A suitable site for the demonstration is being sought.

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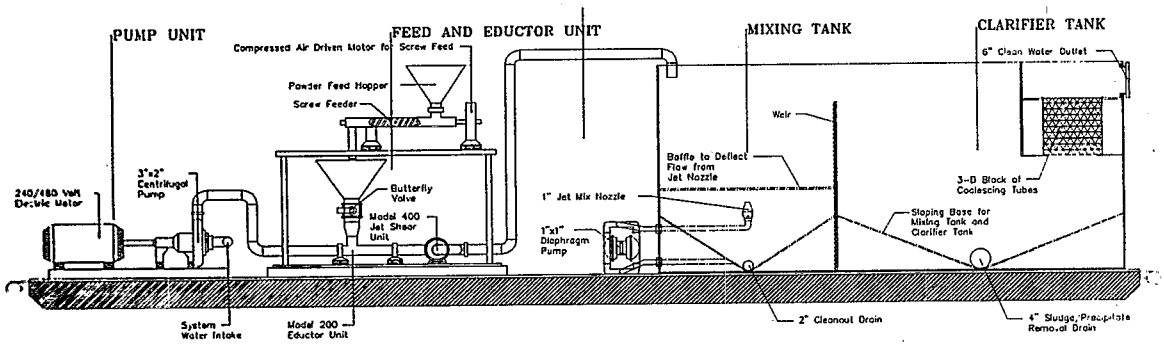
The SITE Program assesses but does not approve or endorse technologies.

TECHTRAN ENVIRONMENTAL, INC.
(Combined Chemical Precipitation, Physical Separation, and Binding Process for Radionuclides and Heavy Metals)

TECHNOLOGY DESCRIPTION:

This technology removes heavy metals and radionuclides from contaminated waters. The process combines the proprietary RHM-1000 powder, as well as a complex mixture of oxides, silicates, and other reactive binding agents, with a contaminated water stream. Selectively enhanced complexing and sorption processes form flocculants and colloids, which are removed through precipitation and physical filtration. The pH, mixing dynamics, processing rates, and powder constituents are optimized through chemical modeling studies and laboratory tests. The contaminants are concentrated in a stabilized filter and precipitate sludge, which is then dewatered. The dewatered sludge meets toxicity characteristic leaching procedure criteria and may, depending on the contaminant, be classified as nonhazardous.

The figure below illustrates the skid-mounted field pilot unit which consists of four main components: 1) pump unit, 2) feed and eductor unit, 3) mixing tank, and 4) clarifier tank. The centrifugal pump unit can deliver up to 50 gallons per minute (gpm) to the system. Water from the pump passes through a restrictor nozzle in the feed and eductor unit, reducing the air pressure at the outlet of an attached hopper unit. RHM-1000 powder is placed in the upper hopper, which is powered by compressed air. The upper hopper delivers a controlled and very low volume of RHM-1000 to the lower hopper. Reduced air pressure draws it into the water stream. The water passes through a two-stage mixing process and is then sent to the mixing tank. A diaphragm pump, driven by compressed air, draws water from the tank's base and reinjects it through a jet nozzle which also draws surrounding water through holes in its base.



TechTran RHM-1000 Pilot Plant

The SITE Program assesses but does not approve or endorse technologies.

The mixed water and RHM-1000 powder pass over a weir into the clarifier tank and through a block of inclined coalescing tubes. Precipitates collect in the tank's base and are drained off. Additional conventional filters can be added to the system outflow as required. The process is designed for continuous operation and can be expanded from 25 to 1,500 gpm.

This process removes heavy metals and radionuclides to drinking water standards. It can also treat trace levels of naturally occurring radioactive materials (NORM) and low-level radioactive wastes, as well as more heavily contaminated waters.

WASTE APPLICABILITY:

This technology can be used to 1) remediate water, sludges and soils contaminated with radionuclides and heavy metals, 2) restore groundwater from mining operations, 3) treat NORM in water or scale from petroleum operations, and 4) remediate manmade radionuclides stored in tanks, pits, barrels, or other containers.

STATUS:

The process was accepted into the SITE Demonstration Program in July 1991. The demonstration is scheduled for late 1994 at a uranium mine facility in Texas.

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The SITE Program assesses but does not approve or endorse technologies.

VORTEC CORPORATION
(Oxidation and Vitrification Process)

TECHNOLOGY DESCRIPTION:

Vortec Corporation (Vortec) has developed an oxidation and vitrification process for remediating soils, sediments, sludges, and mill tailings that have organic, inorganic, and heavy metal contamination. The process can oxidize and vitrify materials introduced as dry granulated materials or slurries.

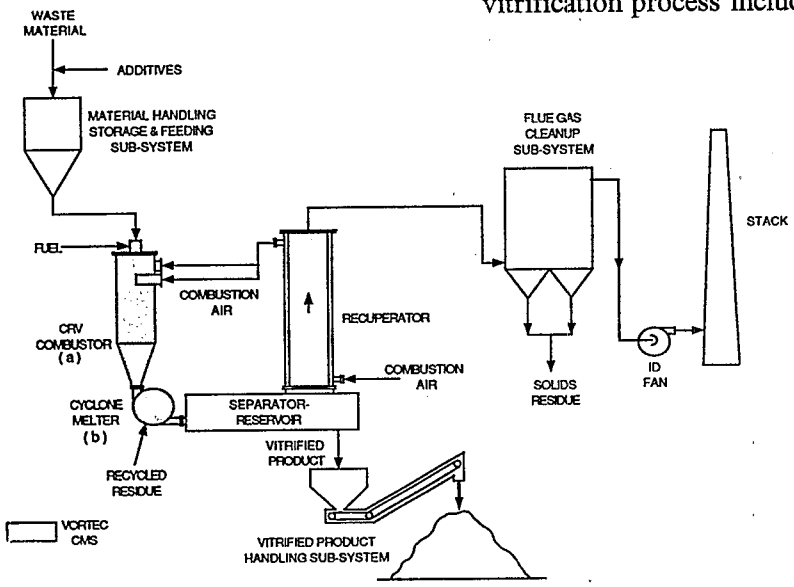
The figure below illustrates the Vortec oxidation and vitrification process. The basic elements of this system include: 1) a combustion and melting system (CMS); 2) a material handling, storage, and feeding subsystem; 3) a vitrified product separation and reservoir assembly; 4) a waste heat recovery air preheater (recuperator); 5) a flue gas cleanup subsystem; and 6) a vitrified product handling subsystem.

The Vortec CMS is the primary thermal processing system and consists of two major assemblies; a counter-rotating vortex in-flight suspension preheater, and a cyclone melter. First, slurried or dry contaminated soil is introduced into the counter rotating vortex (CRV) combustor. The CRV does the following: 1) burns the auxiliary fuel introduced directly into the CRV combustor; 2) preheats the suspended waste materials along with any glass-forming additives mixed with oil; and 3) oxidizes any organic constituents in the soil. The average temperature of materials leaving the CRV combustion chamber is between 2,200 and 2,800 degrees Fahrenheit, depending on the processed soils' melting characteristics.

The preheated solid materials exit the CRV combustor and enter the cyclone melter, where they are dispersed to the chamber walls to form a molten glass product. The vitrified, molten glass product and the exhaust gases exit the cyclone melter through a tangential exit channel and enter a glass- and gas-separation chamber.

The exhaust gases then enter an air preheater for waste heat recovery and are subsequently delivered to an air pollution control subsystem for particulate and acid gas removal. The molten glass product exits the glass- and gas-separation chamber through the tap, and is delivered to a water quench assembly for subsequent disposal.

Unique features of the Vortec oxidation and vitrification process include the following:



Vortec Oxidation and Vitrification Process

The SITE Program assesses but does not approve or endorse technologies.

- Processes solid waste contaminated with both organic and heavy metal contaminants
- Uses various fuels, including gas, oil, coal, and waste
- Handles waste quantities ranging from 5 tons per day to more than 400 tons per day
- Recycles particulate residue collected in the air pollution control subsystem back into the CMS process. These recycled materials are incorporated into the glass product, resulting in zero solid waste discharge
- Produces a vitrified product that is nontoxic according to the EPA's toxicity characteristic leaching procedure (TCLP) standards, immobilizes heavy metals, and has long-term stability

WASTE APPLICABILITY:

The Vortec oxidation and vitrification system treats soils, sediments, sludges, and mill tailings containing organic, inorganic, and heavy metal contamination. Organic materials included with the waste are successfully oxidized by the high temperatures in the combustor. The inorganic constituents in the waste material will determine the amount and type of glass-forming additives required to produce a vitrified product. This process can be modified to produce a glass cullet that consistently meets TCLP requirements.

STATUS:

The Vortec technology was accepted into the SITE Emerging Technology Program in May 1991. Research was completed in winter 1994 and the technology has been invited to participate in the SITE Demonstration Program. The research results will be published in the *Journal of Air and Waste Management* article entitled "Vitrification of Soils Contaminated by Hazardous and/or Radioactive Waste." An Emerging Technology Summary is available from EPA.

The technology has been under development by the U.S. Department of Energy (DOE) and others since 1985. A 20-ton-per-day pilot-scale test facility has been processing nonhazardous industrial waste material since 1988; the vitrified product generated in these tests passes TCLP standards. A preliminary system with a treatment rate of up to 400 tons per day has also been designed. The pilot-scale facility processed a surrogate soil spiked with arsenic, cadmium, chromium, copper, lead, nickel, and zinc compounds. Pilot-testing with a dry, granulated feed stream was completed in June 1992, and the glass product successfully passed TCLP tests. Additional testing with a slurry feedstock was completed in 1993. Transportable systems are being designed for DOE soil remediation.

A transportable demonstration unit for treating contaminated soil will be designed in 1994; construction is scheduled for 1995. Vortec is offering commercial systems and licenses for the CMS technology.

FOR FURTHER INFORMATION:

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The SITE Program assesses but does not approve or endorse technologies.

WESTERN RESEARCH INSTITUTE
(Contained Recovery of Oily Wastes [CROW™])

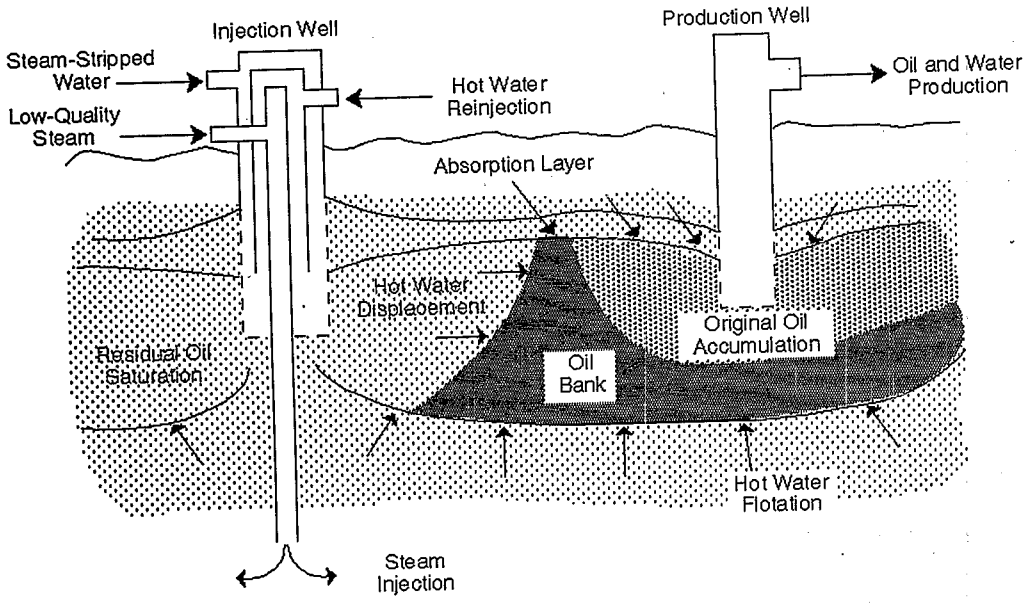
TECHNOLOGY DESCRIPTION:

The contained recovery of oily wastes (CROW™) process recovers oily wastes from the ground by adapting a technology presently used for secondary petroleum recovery and primary production of heavy oil and tar sand bitumen. Steam or hot water displacement moves accumulated oily wastes and water to production wells for aboveground treatment.

Injection and production wells are first installed in soil contaminated with oily wastes (see figure below). If contamination has penetrated into or below the aquifer, low-quality steam can be injected below the organic liquids to dislodge and sweep them upward into the more permeable aquifer soil regions. Hot water is injected above the impermeable soil regions to heat and mobilize the oil waste accumulation. The mobilized wastes are then recovered by hot water displacement.

When the organic wastes are displaced, organic liquid saturation in the subsurface pore space increases, forming a free-fluid bank. The hot water injection displaces the free-fluid bank to the production well. Behind the free-fluid bank, the contaminant saturation is reduced to an immobile residual saturation in the subsurface pore space. The extracted contaminant and water are treated for reuse or discharge.

In situ biological treatment may follow the displacement, which continues until groundwater contaminants are no longer detected in water samples from the site. During treatment, all mobilized organic liquids and water-soluble contaminants are contained within the original boundaries of waste accumulation. Hazardous



CROW™ Subsurface Development

The SITE Program assesses but does not approve or endorse technologies.

materials are contained laterally by groundwater isolation and vertically by organic liquid flotation. Excess water is treated in compliance with discharge regulations.

The CROW™ process removes large portions of contaminant accumulations; stops the downward and lateral migration of organic contaminants; immobilizes any remaining organic wastes as a residual saturation; and reduces the volume, mobility, and toxicity of the contaminants. The process can be used for shallow and deep areas, and can recover light and dense nonaqueous phase liquids. The system uses readily available mobile equipment. Contaminant removal can be increased by adding small quantities of selected biodegradable chemicals in the hot water injection.

WASTE APPLICABILITY:

The CROW™ process can be applied to manufactured gas plant sites, wood treating sites, petroleum-refining facilities, and other areas with soils and aquifers containing light to dense organic liquids such as coal tars, pentachlorophenol (PCP) solutions, chlorinated solvents, creosote, and petroleum by-products. Depth to the contamination is not a limiting factor.

STATUS:

The CROW™ process was tested in the laboratory and at pilot scale under the SITE Emerging Technology Program. The process demonstrated the effectiveness of hot water displacement and the benefits of including chemicals with the hot water. Based on these results, the CROW™ process was invited to participate in the SITE Demonstration Program. The process is being demonstrated at the Pennsylvania Power and Light (PP&L) Brodhead Creek Superfund site at Stroudsburg, Pennsylvania. The site contains an area with high concentrations of by-products from past operations. The demonstration began in September 1994 and will last for 4 months.

Sponsors for this program, in addition to EPA and PP&L, are the Gas Research Institute, the Electric Power Research Institute, and the U.S. Department of Energy. Remediation Technologies, Inc., is assisting Western Research Institute with the demonstration, with emphasis on biological treatment of the produced fluids.

A pilot-scale technology demonstration was completed at a wood treatment site in Minnesota. Over 80 percent of nonaqueous phase liquids were removed in the pilot test, as predicted by treatability studies, and PCP concentrations decreased 500 percent. The full-scale remediation for this site is underway and will include a progressive series of individual but interconnected well patterns. Several other sites are being evaluated.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
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The SITE Program assesses but does not approve or endorse technologies.

WHEELABRATOR TECHNOLOGIES INC.
(WES-Phix Stabilization Process)

TECHNOLOGY DESCRIPTION:

WES-Phix is a patented stabilization process that significantly reduces the solubility of certain heavy metals in solid waste streams by altering the chemical composition of the waste material. The process does not produce a solidified mass, unlike most other stabilization technologies.

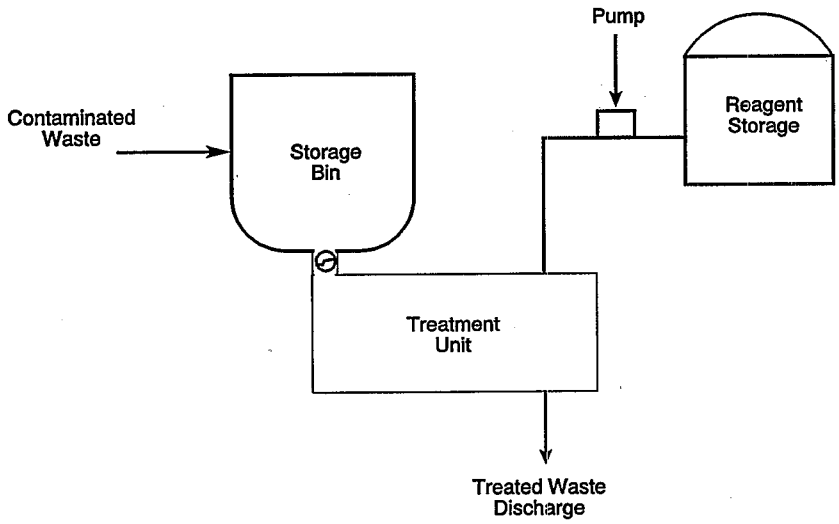
In the first step of the process, waste is fed at a controlled rate into a mixing device, such as a pug mill. The full-scale WES-Phix process uses a pug mill with a capacity of 40 to 200 tons per hour. The stabilization reagent is then added to and mixed with the waste for about 1 minute. Once stabilized, the waste is removed by a conveyor from the end of the mixer. For some wastes containing cadmium, small amounts of lime must also be added.

The WES-Phix process uses a proprietary form of soluble phosphate to form insoluble and highly stable metal phosphate minerals. An important innovative feature of this process is that reaction kinetics are rapid; thus, no curing step is necessary. As a result, treated waste will immediately pass toxicity characteristic leaching procedure (TCLP) requirements for the targeted metals. In addition, using small quantities of liquid phosphate reagent does not increase the stabilized waste volume.

Equipment requirements include a metering device for measuring waste stream delivery rates, a mixer, and a storage tank for the liquid reagent (see figure below). Oversized items such as boulders or wood debris require crushing or screening before treatment. No posttreatment is necessary with this process other than transporting the treated material from the mixer to a staging area. Treated residuals can be transported for final disposal with dump trucks or roll-off container vehicles.

WASTE APPLICABILITY:

This process was originally developed to treat municipal waste combustion ash containing heavy metals. The commercial-scale process has successfully treated over 3 million tons of ash.



WES-Phix Stabilization Process

The SITE Program assesses but does not approve or endorse technologies.

However, data indicate that the technology can also treat contaminated soils, sludges, and baghouse dusts. Recent research indicates that the process is particularly effective at stabilizing lead, cadmium, copper, and zinc in a variety of media, as measured by TCLP and other laboratory leaching tests.

STATUS:

The WES-Phix process was accepted into the SITE Demonstration Program in spring 1993. A suitable demonstration site is being selected.

FOR FURTHER INFORMATION:

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Risk Reduction Engineering Laboratory
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Fax: 908-321-6640

TECHNOLOGY DEVELOPER CONTACT:
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Wheelabrator Technologies Inc.
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603-929-3000
Fax: 603-929-3123

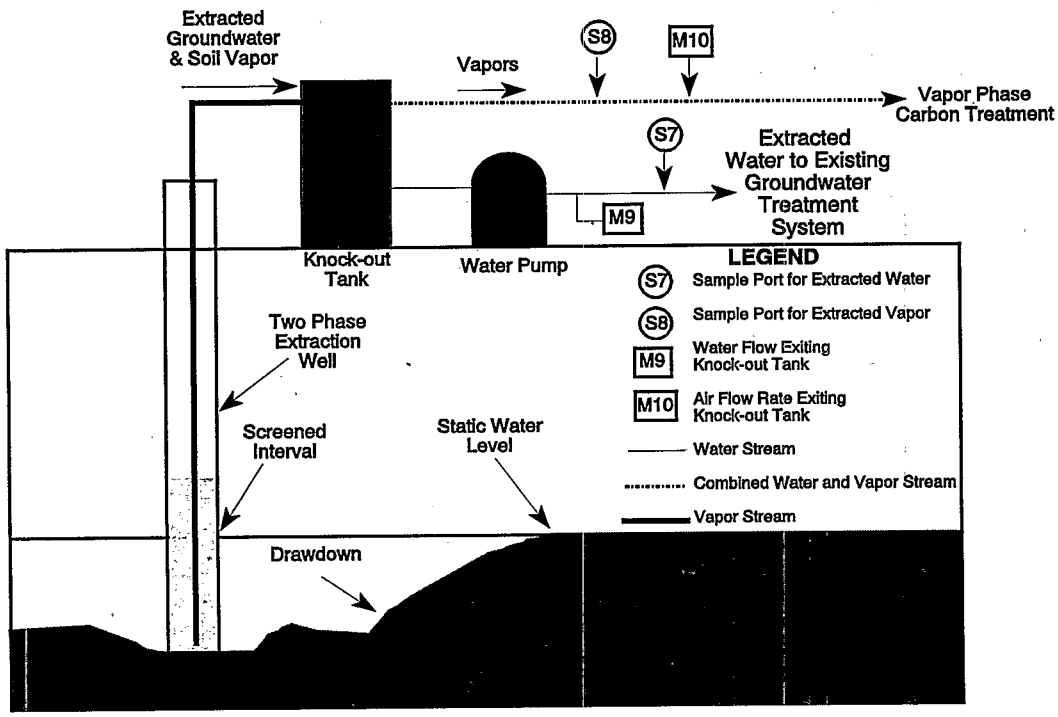
The SITE Program assesses but does not approve or endorse technologies.

XEROX CORPORATION
(Two-Phase Extraction Process)

TECHNOLOGY DESCRIPTION:

The two-phase extraction process was developed as an alternative to conventional pump-and-treat technology, particularly in low conductivity formations such as silts and clays that are impacted by volatile organic compounds (VOC). Two-phase extraction uses a high-vacuum source applied to an extraction tube within a water well to increase groundwater removal rates (consequently the dissolved phase of contamination) and to volatilize and extract that portion of contaminant from the sorbed or free product phases. Vacuum lift of water is not a limiting factor in the application of the technology. Since a mixed vapor/liquid column is extracted from the well, the two-phase extraction technology allows a single piece of equipment (a high-vacuum source) to remove contaminants in both the liquid and vapor phases.

To extract both groundwater and soil vapor from a single extraction well, the two-phase extraction system uses a vacuum pump to apply a high



Process Schematic of the 2-Phase Extraction System

The SITE Program assesses but does not approve or endorse technologies.

vacuum through a central extraction tube, which extends down the well. Soil vapor drawn into the well by the vacuum provides for a high-velocity vapor stream at the bottom tip of the extraction tube, which entrains the contaminated groundwater and lifts it to the ground surface. As the groundwater moves up the tube, more than 90 percent of the VOCs in the water phase are reportedly transferred to the vapor phase. The vapor and water phases are then separated at the surface in a knockout tank. The water phase then requires only carbon polishing prior to discharge, provided that the compounds are adsorbable. The vapor phase is then subjected to carbon treatment, bioremediation, resin regeneration, catalytic oxidation, or other vapor phase treatment (based on contaminant characteristics, mass loadings, and economics), prior to release to the atmosphere.

A kick start system can induce flow and help dewater the well. The flow of atmospheric air can be regulated by adjustment of the gate valve to: 1) optimize the air-to-water flow ratio to minimize water "slug" production at start-up (the term "slug" refers to an irregular pulsation of water through the extraction tube which indicates irregular water flow); 2) maximize tube penetration into the saturated zone; and 3) maximize the groundwater flow rate by optimizing the applied vacuum to the well's annular space.

Typical installation activities require connection of a power supply, piping and vacuum system leveling, connection to the extraction well(s) and connection of vapor-and liquid-phase discharge connections to final treatment process(es).

WASTE APPLICABILITY:

This technology removes VOCs from groundwater and/or soils.

STATUS:

The Xerox two-phase extraction process was accepted into the SITE Demonstration Program in summer 1994. The demonstration began in August 1994 at a contaminated groundwater site at McClellan Air Force Base in Sacramento, California. The demonstration is expected to continue for 2 to 6 months.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
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Fax: 716-422-9211

Bud Hoda
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916-643-1742, ext. 355
Fax: 916-643-0827

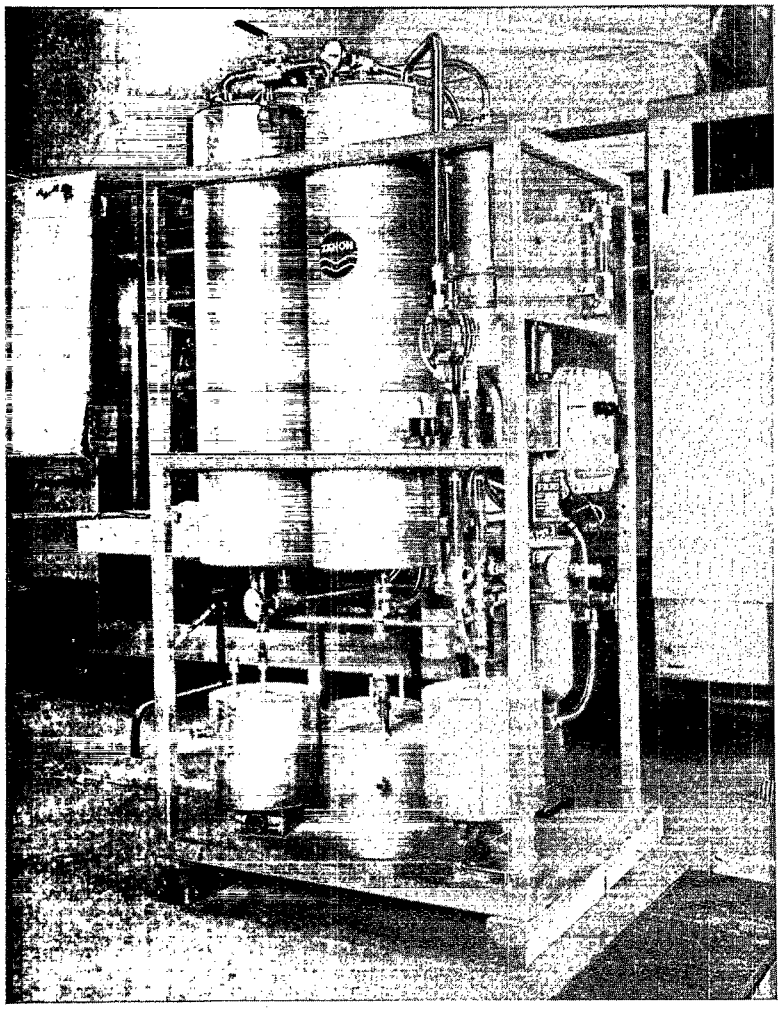
The SITE Program assesses but does not approve or endorse technologies.

ZENON ENVIRONMENTAL INC.
(Cross-Flow Pervaporation System)

TECHNOLOGY DESCRIPTION:

Pervaporation is a membrane process for removing volatile organic compounds (VOC) from contaminated water. Permeable membranes selectively remove VOCs from the contaminated water. VOCs diffuse from the membrane-water interface through the membrane. A condenser traps and contains the permeating vapors, condensing vapors to liquid, and alleviating fugitive emissions. The condensed organic materials represent only a very small fraction of the initial wastewater volume and may be subsequently disposed of at significant cost savings. This process may also treat industrial waste streams and recover organics for later use.

Zenon Environmental Inc. (Zenon) has developed and built a pilot-scale pervaporation system for Environment Canada's Emergencies Engineering Division that is skid-mounted and compact. The membrane modules in this system consist of hollow fibers that are configured for maximum mass transfer efficiency. Removal to



Pilot Cross-Flow Pervaporation System

The SITE Program assesses but does not approve or endorse technologies.

levels less than one part per billion (ppb) has been demonstrated. For flow rates of less than 1 gallon per minute, this unit can remove 99.99 percent of VOCs. This high removal capacity, plus containment of fugitive emissions and minimal pretreatment requirements, are the primary advantages of this technology when compared with air stripping followed by gas-phase carbon adsorption.

WASTE APPLICABILITY:

Pervaporation can be applied to aqueous waste streams such as groundwater, lagoons, leachate, and rinsewaters that are contaminated with VOCs like solvents, degreasers, and gasoline. The technology is applicable to the types of aqueous wastes currently treated by carbon adsorption, air stripping, and steam stripping.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in January 1989. Based on results from the Emerging Technology Program, Zenon was invited to demonstrate the technology in the Demonstration Program.

Under the 1992 SITE Emerging Technology Program, Wastewater Technology Centre compared costs for Zenon's technology versus air stripping and activated carbon. The comparison showed that pervaporation can be competitive with air stripping and activated carbon. The cost competitiveness of pervaporation increases with VOC concentration.

A pilot-scale pervaporation unit was field tested in late 1993, near Burlington, Ontario, Canada, at a site containing groundwater contaminated with low concentrations of petroleum hydrocarbons. The unit's contaminant removal efficiency was better than 99 percent.

A full-scale SITE demonstration is scheduled for fall 1994 at Naval Air Station North Island in San Diego, California. The technology will treat 100,000 gallons of groundwater contaminated with waste solvents, waste paint materials, electroplating wastes, and various petroleum hydrocarbons.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
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The SITE Program assesses but does not approve or endorse technologies.

ZENON ENVIRONMENTAL INC.
(ZenoGem™ Process)

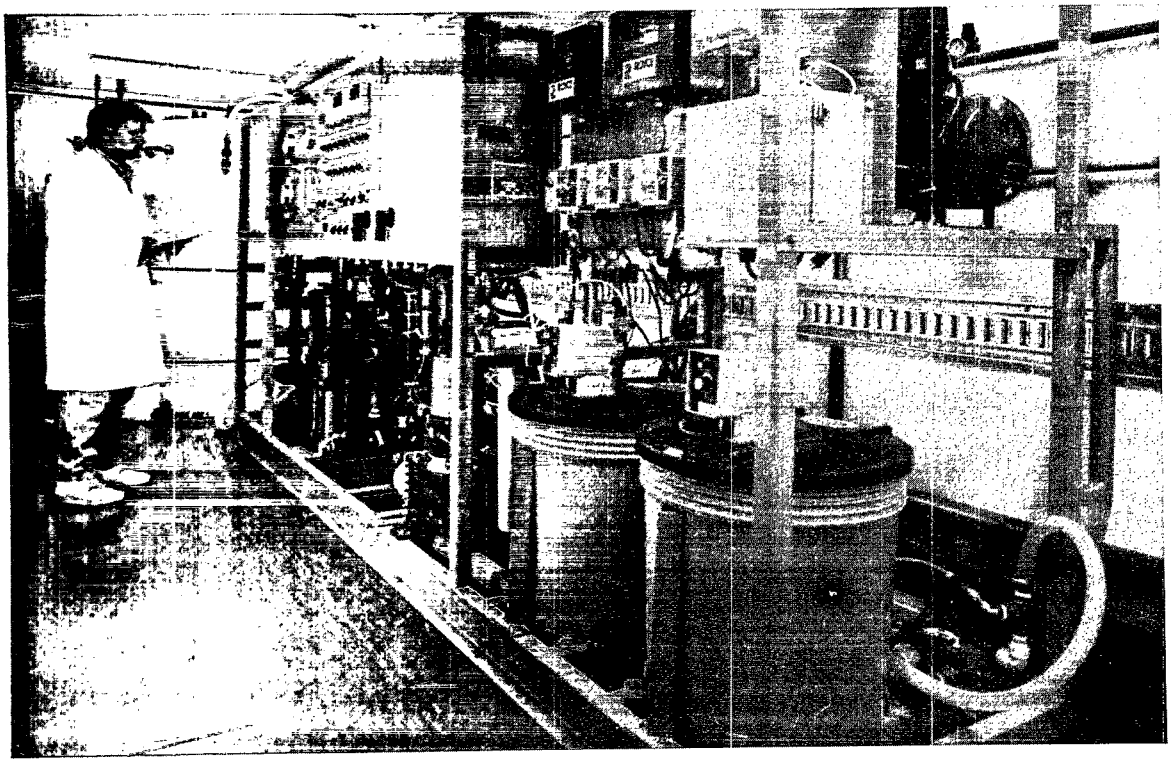
TECHNOLOGY DESCRIPTION:

Zenon Environmental Inc.'s, ZenoGem™ Process consists of a bioreactor combined with an ultrafiltration membrane system (see photograph below). Combining these technologies yields a system that treats high strength wastes at long sludge retention time but very short hydraulic residence time. As a result, the bioreactor's size is significantly reduced. Membrane filtration reduces the turbidity of the treated waste to less than 1 nephelometric turbidity unit.

During the ZenoGem™ Process, wastewater contaminated with organic compounds first enters the bioreactor, where contaminants are biologically degraded. Next, the process pump circulates the biomass through the ultrafiltration membrane system, or ultrafilter. The ultrafilter separates treated water from biological solids and soluble materials with higher molecular weights, including emulsified oil. The solids and soluble materials are then recycled to the bioreactor. The ZenoGem™ Process captures higher molecular weight materials that would otherwise pass through conventional clarifiers and filters.

The ZenoGem™ Process mobile unit is mounted on a 48-foot trailer and consists of the following seven components:

- Pretreatment system: reduces contaminants to limits required for optimum ultrafilter performance.
- Polyethylene equalization tank: reduces the normal flow concentration fluctuations in the system.



ZenoGem™ Process

The SITE Program assesses but does not approve or endorse technologies.

- Polyethylene bioreactor tank: contains the bacterial culture that breaks down organic contaminants. Air may be partially recycled to the reactor to reduce volatile organic emissions, when necessary.
- Process pump: ensures proper flow and pressure for optimum system performance.
- Ultrafiltration system: contains rugged, clog-free, tubular membrane modules.
- Clean-in-place tank: includes all the necessary valves, instrumentation, and controls to clean the membrane filters.
- Control panel and computer: monitors remote and local data and alarms.

The system's capacity is about 500 to 1,000 gallons of wastewater per day. The capacity depends on the ultrafilters' flux rates and the required hydraulic retention time for the bioreactor.

WASTE APPLICABILITY:

The ZenoGem™ Process is designed to remove biodegradable materials, including most organic contaminants, from wastewater to produce a high quality effluent. The process consistently nitrifies organics, and can also denitrify organics with the addition of an anoxic bioreactor. The process is limited to aqueous media and may be used to treat leachates and contaminated groundwater. Soils can be treated indirectly by treating the effluents from soil washing operations.

STATUS:

The ZenoGem™ Process was accepted into the SITE Demonstration Program in summer 1992. The demonstration is underway at the Nascolite Superfund site in Millville, New Jersey and will be completed in November 1994.

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Fax: 905-639-1812

The SITE Program assesses but does not approve or endorse technologies.

ZIMPRO ENVIRONMENTAL, INC.
(PACT® Wastewater Treatment System)

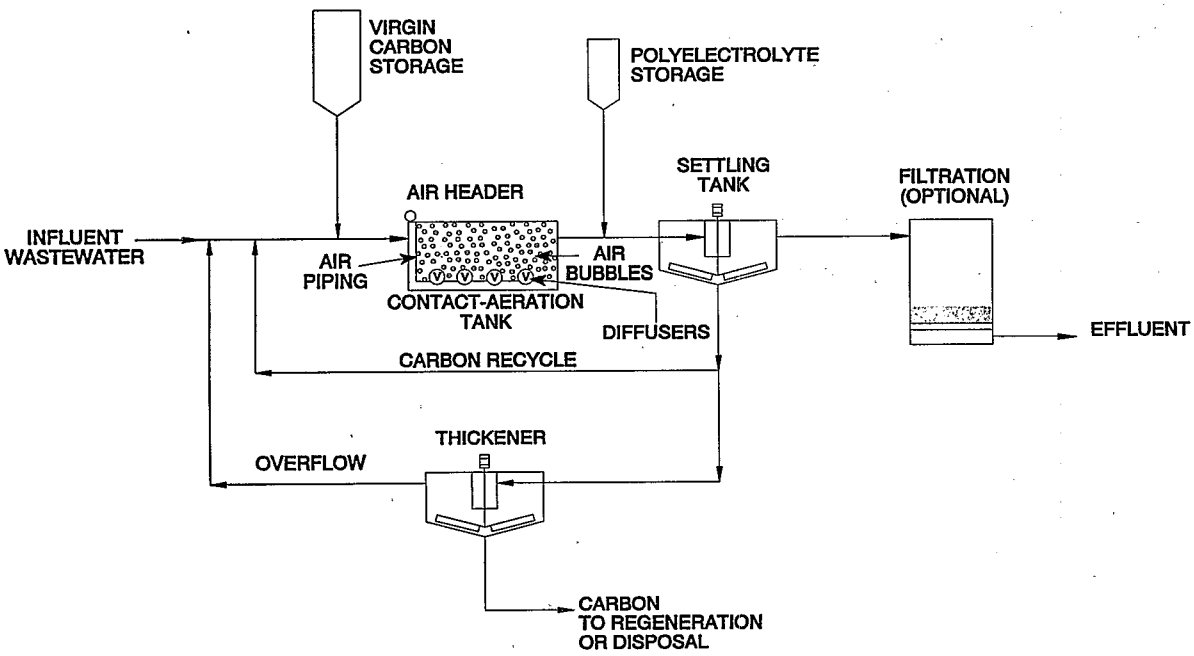
TECHNOLOGY DESCRIPTION:

Zimpro Environmental, Inc. (Zimpro), has adapted the PACT® wastewater treatment system to treat contaminated groundwaters encountered at many Superfund sites. The system combines biological treatment and powdered activated carbon (PAC) adsorption to achieve treatment standards not readily attainable with conventional technologies. The mobile, trailer-mounted system can treat 2,500 to 10,000 gallons of wastewater per day. Larger stationary systems, treating up to 53 million gallons per day, are already in operation.

Living microorganisms (biomass) and PAC contact the wastewater in the aeration tank. The biomass removes biodegradable organic contaminants, while PAC enhances the adsorption of toxic organic compounds. The figure below depicts a flow diagram of a single-stage PACT® wastewater treatment system.

The system's removal efficiency depends on the influent waste characteristics and the system's operating parameters. Important characteristics include biodegradability, adsorbability, and concentrations of toxic inorganic compounds, such as heavy metals.

The technology adjusts to the specific waste stream by controlling the flow rate of the influent waste, recycle streams, and air. The system is controlled by varying the concentration of PAC in the system, adjusting the retention time of the PAC-biomass mixed liquid, and adjusting the waste to biomass ratio. If necessary, the temperature and pH of incoming waste can be adjusted and nutrients added.



PACT® Wastewater Treatment System

The SITE Program assesses but does not approve or endorse technologies.

After the aeration cycle is completed, PAC with adsorbed organics, biomass, and inert solids are removed from the settling tank. A portion of the removed solids are returned to the contact-aeration tank. Excess solids are diverted to the thickener, where the solids are concentrated. Overflow from the thickener is returned to the contact-aeration tank, and the concentrated solids are removed. Dewatered solids may be regenerated to recover PAC.

A two-stage PACT® system can be used where environmental regulations require virtual elimination of organic priority pollutants or toxicity in the treated effluent. In the first stage contact-aeration tank, a high concentration of biomass and PAC removes most of the contaminants. The second-stage contact-aeration tank polishes the first-stage effluent. Virgin PAC is added just ahead of the second stage and solids are returned to the first stage to increase overall process efficiency. Excess solids removed from the first stage are treated as described in the single-stage PACT® system. Zimpro has also developed anaerobic and multi-staged anaerobic-aerobic PACT® systems.

WASTE APPLICABILITY:

The PACT® system can be applied to municipal and industrial wastewaters, as well as groundwater and leachates containing hazardous organic pollutants. The PACT® has successfully treated various industrial wastewaters, including chemical plant, dye production, pharmaceutical, refinery, and synthetic fuel wastewaters, in addition to contaminated groundwater and mixed industrial and municipal wastewater.

In general, the system can treat liquid wastes with a chemical oxygen demand of up to 60,000 parts per million (ppm), including toxic volatile organic compounds up to 1,000 ppm. Treatability studies indicate that the system can reduce the organics in contaminated groundwater from several hundred ppm to below detection limits (parts per billion range).

STATUS:

The PACT® system was accepted into the SITE Program in 1987. Contaminated groundwater from several sites has been tested and found suitable for treatment. A treatability study report has been prepared. Site-specific conditions have prevented demonstration testing in several instances; however, additional sites are now being evaluated for a full-scale demonstration of the PACT® system.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
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715-359-7211
Fax: 715-355-3219

The SITE Program assesses but does not approve or endorse technologies.

EMERGING TECHNOLOGY PROGRAM

The Emerging Technology Program provides an opportunity to research and develop technologies at bench- and pilot-scale levels. The goal is to promote and support the development of alternative technologies for field applications at Superfund site remediations.

Technologies are solicited yearly for the Emerging Technology Program through Requests for Preproposals. After a technical review of the preproposals, selected candidates are invited to submit a Cooperative Agreement Application and detailed project proposal that undergoes another full technical review. The Cooperative Agreement between EPA and the technology developer requires cost sharing. Projects are considered for either a 1- or 2-year developmental effort, providing awards of up to $150,000 per year, with a maximum of $300,000 over 2 years. Second-year funding depends on achieving significant progress during the first year. After the second year or significant progress, emerging technologies may be considered for the SITE Demonstration Program.

To enable EPA to accept additional technologies into the Emerging Technology Program, Interagency Agreements have been made between EPA and the U.S. Department of Energy (DOE) and the U.S. Air Force (USAF). DOE has helped fund 21 projects, and USAF has helped fund eight projects.

Eight solicitations have been issued: November 1987 (E01), July 1988 (E02), July 1989 (E03), July 1990 (E04), July 1991 (E05), July 1992 (E06), and July 1993 (E07), and July 1994 (E08).

Thirty-nine Emerging Technology projects have been completed, and several more will be completed in 1995. Four technologies, Babcock & Wilcox Co.'s Cyclone Furnace, Cognis, Inc.'s, Chemical Treatment, High Voltage Environmental Applications, Inc.'s, High-Energy Electron Beam Irradiation technology, and J.R. Simplot's SABRE™ Process, have been demonstrated under the SITE Demonstration Program. Fifteen more Emerging Technology projects are participating in the Demonstration Program.

Completed Emerging Technology Program participants are presented in alphabetical order in Table 3 and in the technology profiles that follow; ongoing program participants are presented in alphabetical order in Table 4 and in the profiles that follow.

TABLE 3

Completed SITE Emerging Technology Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
ABB Environmental Services, Inc., Wakefield, MA (E03)*	Two-Zone, Plume Interception, In Situ Treatment Technology	Jaret Johnson 617-245-6606	Ronald Lewis 513-569-7856	Groundwater, Wastewater, Soil	Inorganic Chloride	Chlorinated and Nonchlorinated Solvents
AEA Technology, National Environmental Technology Centre (formerly Warren Spring Laboratory), Abingdon, England (E04)	Soil Separation and Washing Process	Peter Wood 011-44-235-463194	Mary Stinson 908-321-6683	Soil, Sludge, Sediment	Metals	Petroleum Hydrocarbons, PAHs
Allis Mineral Systems, Waukesha, WI (E03)	PYROKILN THERMAL ENCAPSULATION Process	John Lees 414-798-6265 Glenn Heian 414-762-1190	Marta K. Richards 513-569-7692	Soil, Sludge	Most Metallic Compounds	Halogenated and Nonhalogenated Organics, Petroleum Products
Aluminum Company of America (formerly ALCOA Separation Technology, Inc.),** Pittsburgh, PA (E03)	Bioscrubber	Paul Liu 412-826-3711	Paul dePercin 513-569-7797	Airstreams from Soil, Water, and Air Decontamination Processes	Not Applicable	Most Volatile Organics
ART International, Inc. (formerly Enviro-Sciences, Inc.), Denville, NJ (E03)	Low-Energy Extraction Process	Werner Steiner 201-627-7601	Jack Hubbard 513-569-7507	Soil, Sludge, Sediment	Not Applicable	Tar, Creosote, PCBs, Chlorinated Hydrocarbons, PAHs, Pesticides
Atomic Energy of Canada, Limited, Chalk River, Ontario, Canada (E01)	Chemical Treatment and Ultrafiltration	Leo Buckley 613-584-3311 Phil Campbell 800-872-2325	John Martin 513-569-7758	Groundwater, Leachate, Wastewater	Heavy Metals	Not Applicable
Babcock & Wilcox Co.,** Alliance, OH (E02)	Cyclone Furnace	Dorothy Haidet 216-829-7395	Laurel Staley 513-569-7863	Solids, Soil, Sludge	Heavy Metals, Radionuclides	Nonspecific Organics
Battelle Memorial Institute, Columbus, OH (E01)	In Situ Electroacoustic Soil Decontamination	Satya Chauhan 614-424-4812	Jonathan Herrmann 513-569-7839	Soil	Nonspecific Metals	Nonspecific Hydrocarbons
Bio-Recovery Systems, Inc.,** Las Cruces, NM (E01)	Biological Sorption	Mike Hosea 505-523-0405 800-697-2001	Ronald Lewis 513-569-7856	Groundwater, Leachate, Wastewater	Heavy Metals, Uranium	Not Applicable

* Solicitation Number
** Invited to participate in the SITE Demonstration Program

TABLE 3 (continued)

Completed SITE Emerging Technology Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
BioTrol, Inc., Eden Prairie, MN (E03)	Methanotrophic Bioreactor System	Durrell Dobbins 612-942-8032	David Smith 303-293-1475	Water	Not Applicable	Halogenated Hydrocarbons
Center for Hazardous Materials Research, Pittsburgh, PA (E03)	Acid Extraction Treatment System	Stephen Paff 412-826-5321	George Moore 513-569-7991	Soil	Heavy Metals	Not Applicable
Center for Hazardous Materials Research, Pittsburgh, PA (E04)	Smelting Lead-Containing Waste	Stephen Paff 412-826-5321	Laurel Staley 513-569-7863	Solids, Lead-Containing Waste	Lead	Not Applicable
Cognis, Inc.,** Santa Rosa, CA (E05)	Chemical Treatment	Bill Fristad 707-576-6235	Michael Royer 908-321-6633	Soil, Sludge, Sediment	Heavy Metals, Lead	Not Applicable
Colorado School of Mines,** Golden, CO (E01)	Constructed Wetlands-Based Treatment	Thomas Wildeman 303-273-3642	Edward Bates 513-569-7774	Acid Mine Drainage	Metals	Not Applicable
Electrokinetics Inc.,** Baton Rouge, LA (E03)	Electro-Klean™ Electrokinetic Soil Processing	Yalcin Acar and Robert Marks 504-388-3992	Randy Parker 513-569-7271	Soil	Heavy Metals and Other Inorganics, Radionuclides	Nonspecific Organics
Electron Beam Research Facility, Florida International University, and University of Miami,** Miami, FL (E03)	High-Energy Electron Irradiation	William Cooper 305-348-3049 Charles Kurucz 305-284-6595 Thomas Waite 305-593-5330	Franklin Alvarez 513-569-7631	Water Streams, Sludge	Not Applicable	Most Organics
Electro-Pure Systems, Inc., Amherst, NY (E02)	Alternating Current Electrocoagulation Technology	James LaDue 716-691-2610 716-691-2613	Randy Parker 513-569-7271	Groundwater, Wastewater, Leachate	Heavy Metals	Petroleum By-products, Coal-Tar Derivatives
Energy and Environmental Engineering, Inc., East Cambridge, MA (E01)	PhotoCAT™ Process	James Porter 617-666-5500	Ronald Lewis 513-569-7856	Groundwater, Wastewater	Not Applicable	Various Organics, PCP, PCBs, Dioxins, Pesticides
Energy and Environmental Research Corporation, Irvine, CA (E03)	Hybrid Fluidized Bed System	Richard Koppang 714-859-8851	Teri Richardson 513-569-7949	Solids, Sludge	Volatile Inorganics	Nonspecific Organics

** Invited to participate in the SITE Demonstration Program

TABLE 3 (continued)

Completed SITE Emerging Technology Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Ferro Corporation, Independence, OH (E03)	Waste Vitrification Through Electric Melting	Emilio Spinosa 216-641-8580	Randy Parker 513-569-7271	Soil, Sludge, Sediment	Nonspecific Inorganics	Nonspecific Organics
Hazardous Substance Management Research Center at New Jersey Institute of Technology, Newark, NJ (E04)	Pneumatic Fracturing/ Bioremedation	John Schuring 201-596-5849	Uwe Frank 908-321-6626	Soil	Not Applicable	Petroluem Hydrocarbons, Benzene, Toluene, Xylene
Institute of Gas Technology,** Des Plaines, IL (E04)	Chemical and Biological Treatment	Robert Kelley 708-768-0722	Ronald Lewis 513-569-7856	Soil, Sludge, Groundwater, Surface Water	Not Applicable	Most Organics
Institute of Gas Technology,** Des Plaines, IL (E03)	Fluid Extraction - Biological Degradation Process	Robert Paterek 708-768-0500	Annette Gatchett 513-569-7697	Soil, Solids	Not Applicable	Hydrocarbons, Nonhalogenated Aliphatic Hydrocarbons, PAHs
IT Corporation, Knoxville, TN (E02)	Batch Steam Distillation and Metal Extraction	Robert Fox 615-690-3211	Ronald Lewis 513-569-7856	Soil, Sludge	Heavy Metals, Nonspecific Inorganics	Nonspecific Organics
IT Corporation, Knoxville, TN (E03)	Photolytic and Biological Soil Detoxification	Robert Fox 615-690-3211	Randy Parker 513-569-7271	Soil	Not Applicable	PCBs, Dioxins, PAHs, Other Nonspecific Organics
Matrix Photocatalytic Inc. (formerly Nutech Environmental),** London, Ontario, Canada (E05)	Photocatalytic Water Treatment	Bob Henderson 519-660-8669	John Ireland 513-569-7413	Wastewater, Groundwater, Process Water	Nonspecific Inorganics	PCBs, PCDDs, PCDFs, Chlorinated Alkenes, Chlorinated Phenols
Membrane Technology and Research, Inc., Menlo Park, CA (E02)	VaporSep™ Membrane Process	David Dortmundt or Marc Jacobs 415-328-2228	Paul dePercin 513-569-7797	Gaseous Waste Streams	Not Applicable	Halogenated and Nonhalogenated Organics
Montana College of Mineral Science & Technology, Butte, MT (E03)	Air-Sparged Hydrocyclone	Theodore Jordan 406-496-4112 406-496-1473	Euguene Harris 513-569-7862	Aqueous Solutions	Low-Concentration Metals	Not Applicable

** Invited to participate in the SITE Demonstration Program

TABLE 3 (continued)

Completed SITE Emerging Technology Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Montana College of Mineral Science and Technology, Butte, MT (E05)	Campbell Centrifugal Jig	Gordon Ziesing 406-496-4112 406-496-1473	Jack Hubbard 513-569-7507	Soil, Mine Tailings	Heavy Metals	Not Applicable
New Jersey Institute of Technology, Newark, NJ (E03)	GHEA Associates Process	Itzhak Gotlieb 201-596-5862	Annette Gatchett 513-569-7697	Soil, Sludge, Sediment, Water, Industrial Effluent	Heavy Metals	Most Organics, VOCs, SVOCs
PSI Technologies, A Division of Physical Sciences Inc., Andover, MA (E04)	Metals Immobilization and Decontamination of Aggregate Solids	Joseph Morency 508-689-0003	Mark Meckes 513-569-7348	Soil, Sludge, Sediment	Heavy Metals, Volatile Metals	Low Volatile Organics, Organometallics
Pulse Sciences, Inc., San Leandro, CA (E04)	X-Ray Treatment of Aqueous Solutions	Vernon Bailey 510-632-5100	Esperanza Piano Renard 908-321-4355	Water	Not Applicable	VOCs, SVOCs
Purus, Inc.,** San Jose, CA (E04)	Photolytic Oxidation Process	Bart Mass 408-955-1000	Norma Lewis 513-569-7665	Soil, Groundwater	Not Applicable	VOCs
J.R. Simplot,** Pocatello, ID (E03)	The SABRE™ Process	Russell Kaake 208-234-5367	Wendy Davis-Hoover 513-569-7206	Soil, Sludge	Not Applicable	Nitroaromatics
Trinity Environmental Technologies, Inc., Mound Valley, KS (E03)	PCB- and Organochlorine-Contaminated Soil Detoxification	Duane Koszalka 316-328-3222	Paul dePercin 513-569-7797	Solids, Sludge	Not Applicable	PCBs, PCP, and Other Chlorinated Hydrocarbon Compounds
University of Washington, Seattle, WA (E02)	Adsorptive Filtration	Mark Benjamin 206-543-7645	Norma Lewis 513-569-7665	Aqueous Waste Streams	Metals, Other Nonspecific Inorganics	Not Applicable
Vortec Corporation,** Collegeville, PA (E04)	Oxidation and Vitrification Process	James Hnat 610-489-2255	Teri Richardson 513-569-7949	Soil, Sludge, Sediment, Mill Tailings	Metals, Other Nonspecific Inorganics	Nonspecific Organics
Wastewater Technology Centre,** Burlington, Ontario, Canada (E02)	Cross-Flow Pervaporation System	Rob Booth 905-336-4689 R. Philip Canning 905-639-6320	John Martin 513-569-7758	Groundwater, Leachate, Wastewater	Not Applicable	VOCs, Solvents, Petroleum Hydrocarbons

** Invited to participate in the SITE Demonstration Program

TABLE 3 (continued)

Completed SITE Emerging Technology Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Western Research Institute;** Laramie, WY (E01)	Contained Recovery of Oily Wastes (CROW™)	Lyle Johnson 307-721-2281	Eugene Harris 513-569-7862	Soil, Water	Not Applicable	Coal Tar Derivatives, Petroleum By-products, Pentachlorophenol Solutions, Chlorinated Solvents, Creosote

** Invited to participate in the SITE Demonstration Program

ABB ENVIRONMENTAL SERVICES, INC.
(Two-Zone, Plume Interception, In Situ Treatment Strategy)

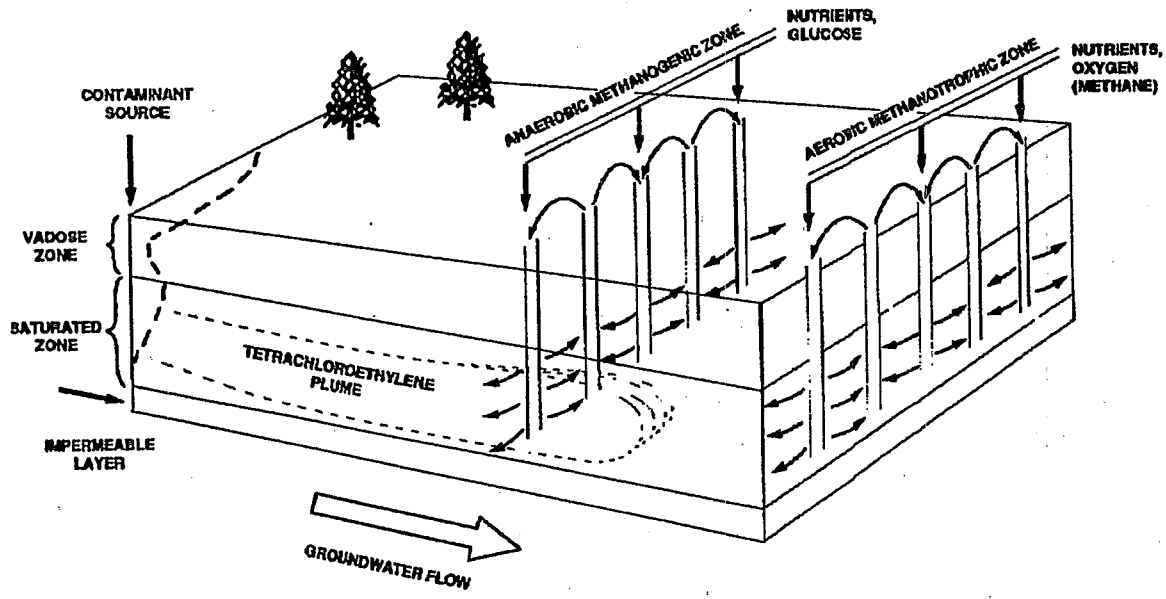
TECHNOLOGY DESCRIPTION:

The two-zone, plume interception, in situ treatment strategy is designed to treat chlorinated and nonchlorinated organic compounds in saturated soils and groundwater under sequencing anaerobic/aerobic conditions. An in situ anaerobic/aerobic system will be applied to constitute a treatment train that biodegrades a wide assortment of chlorinated and nonchlorinated compounds.

Anaerobic and aerobic conditions are produced in two distinct hydraulically-controlled saturated soil zones. Groundwater passes through each zone as it is recirculated through the treatment area. The first zone, the anaerobic zone, is designed to partially dechlorinate highly chlorinated solvents such as tetrachlorethene (PCE), trichloroethene (TCE), and 1,1,1-trichloroethane (TCA) with natural biological processes. The second zone, the aerobic zone, is designed to biologically oxidize the partially dechlorinated products from the first zone, as well as other compounds that were not susceptible to the anaerobic treatment phase.

The first stage of the two-zone, plume interception, in situ treatment strategy encourages anaerobic (reducing) conditions in the aquifer. Anaerobic conditions are produced or enhanced in the target treatment zone by introducing a primary carbon source, such as glucose or acetate, and mineral nutrients, such as nitrogen and phosphorus. When proper anaerobic conditions are attained in the anaerobic zone, the target contaminants are reduced. For example, PCE is dechlorinated to TCE, and TCE is dechlorinated to dichloroethene (DCE) and vinyl chloride.

The second stage of the treatment strategy is designed to promote aerobic biodegradation in the aquifer. Aerobic conditions are produced or enhanced in the target treatment zone by introducing oxygen, mineral nutrients such as nitrogen and phosphorus, and possibly an additional



Two-Zone Plume Interception In Situ Treatment Strategy

The SITE Program assesses but does not approve or endorse technologies.

carbon source, such as methane. When proper aerobic conditions are attained in the aerobic zone, partially dechlorinated products and other target compounds from the first zone will be oxidized. For example, less-chlorinated ethenes such as DCE and vinyl chloride will be cometabolized during the aerobic microbiological degradation of methane.

The treatment strategy is designed to biologically remediate subsoils by enhancing indigenous microorganism activity. In the event that indigenous bacteria populations do not provide the adequate anaerobic or aerobic results, specially-adapted cultures can be introduced to the aquifer. These cultures are introduced using media-filled trenches that can support added microbial growth.

WASTE APPLICABILITY:

The two-zone, plume interception, in situ treatment strategy treats groundwater and saturated soils containing chlorinated and nonchlorinated organic compounds, biomass, and inorganic chloride.

STATUS:

The two-zone, plume interception, in situ treatment strategy was accepted into the SITE Emerging Technology Program in July 1989. Optimal treatment parameters for field testing were investigated in bench-scale soil aquifer simulators. The bench-scale tests' objectives were to 1) determine factors affecting the development of each zone, 2) evaluate indigenous bacterial communities, 3) demonstrate treatment of chlorinated and nonchlorinated solvent mixtures, and 4) develop a model for the field remediation design. A final report on the bench-scale testing results will be available from EPA in early 1995. The developer is currently evaluating several sites for a field demonstration of this technology.

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The SITE Program assesses but does not approve or endorse technologies.

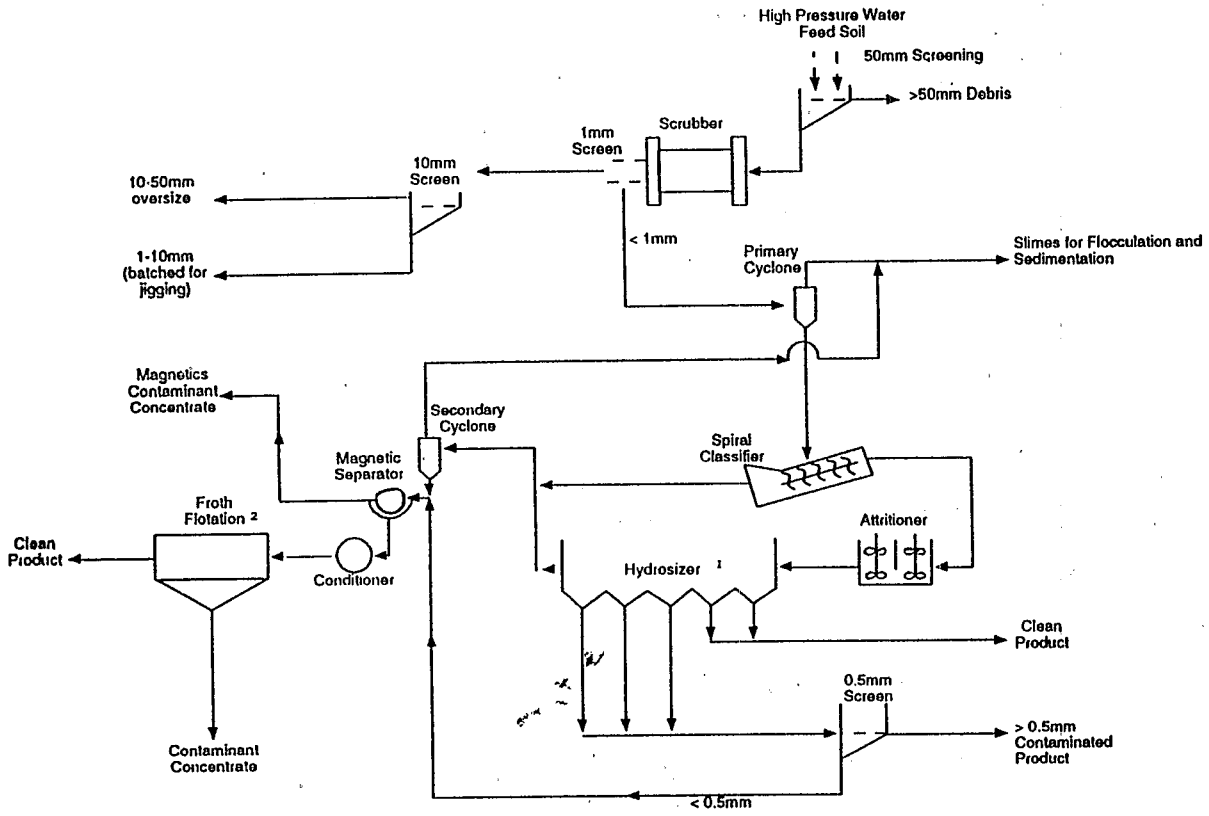
AEA TECHNOLOGY, NATIONAL ENVIRONMENTAL TECHNOLOGY CENTRE
(formerly WARREN SPRING LABORATORY)
(Soil Separation and Washing Process)

TECHNOLOGY DESCRIPTION:

The National Environmental Technology Centre of AEA Technology is investigating potential mineral processing techniques for soil separation and washing. The process can be used 1) as a stand alone volume reduction process where contaminated products are disposed of in landfills; or 2) as a pretreatment technology before secondary treatment or disposal. The process is based on mineral processing equipment; a schematic diagram of the process is shown in the figure below.

The process combines equipment for size fractionation, density separation, and froth flotation. The exact combination and sequence of equipment depends on the nature of the specific material to be treated and contaminant distribution. Material content and contaminant distribution are determined by customized laboratory characterization procedures.

A typical operation involves wet screening at 50 millimeters (mm) with high pressure water jets. Material measuring less than 50 mm enters a washing mill containing a scrubbing medium.



1 Alternative option is to use spiral separator
2 Alternative option is to use multi-gravity separator

Schematic Diagram of the Soil Separation and Washing Process

The SITE Program assesses but does not approve or endorse technologies.

The mill overflow is screened at 1 mm, again under a water jet. Material measuring 1 to 50 mm is further screened at 10 mm. Material measuring less than 1 mm enters a hydrocyclone operating to separate at approximately 10 micrometers (μm). The fraction measuring 10 mm to less than 1 mm is partially dewatered using a spiral classifier prior to a separation stage based on the combined parameters of size and density. A hydrosizer, or alternatively a spiral, can be used for this process. The siliceous course product from the hydrosizer is dewatered and stockpiled without further treatment. The medium product from the hydrosizer is screened at 500 μm prior to entering a magnetic separator, while the fine/light product is hydrocycloned prior to entering the magnetic separator. Following magnetic separation, the material enters one or more froth flotation stages, or alternatively a gravity separation stage using a multi-gravity separator. These stages produce a contaminant concentrate and leave the remaining material relatively contaminant free.

WASTE APPLICABILITY:

The technology is being developed to remove metals, petroleum hydrocarbons, and polynuclear aromatic hydrocarbons from soil. Sediments and certain industrial wastes such as sludges may also be candidates for treatment.

The soil selected for a pilot-scale operation is from a gasworks; other applications include soils from petrochemical plants, pickling plants, industrial chemical plants, coke manufacturers, iron and steel manufacturing plants and foundries.

STATUS:

The technology was accepted into the SITE Emerging Technology Program in July 1991.

The project consisted of the initial characterization in the laboratory of contaminated soils from three different locations. One soil, from a gasworks, was then selected for a pilot-scale operation using a circuit designed to exploit differences in contamination distribution identified in the soil during the laboratory characterization.

The pilot-scale operation was conducted on about 30 tons of soil at a throughput of about 0.5-1 ton per hour. Several test runs were conducted to permit a comparison of the effectiveness of different equipment combinations.

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The SITE Program assesses but does not approve or endorse technologies.

ALLIS MINERAL SYSTEMS
(PYROKILN THERMAL ENCAPSULATION Process)

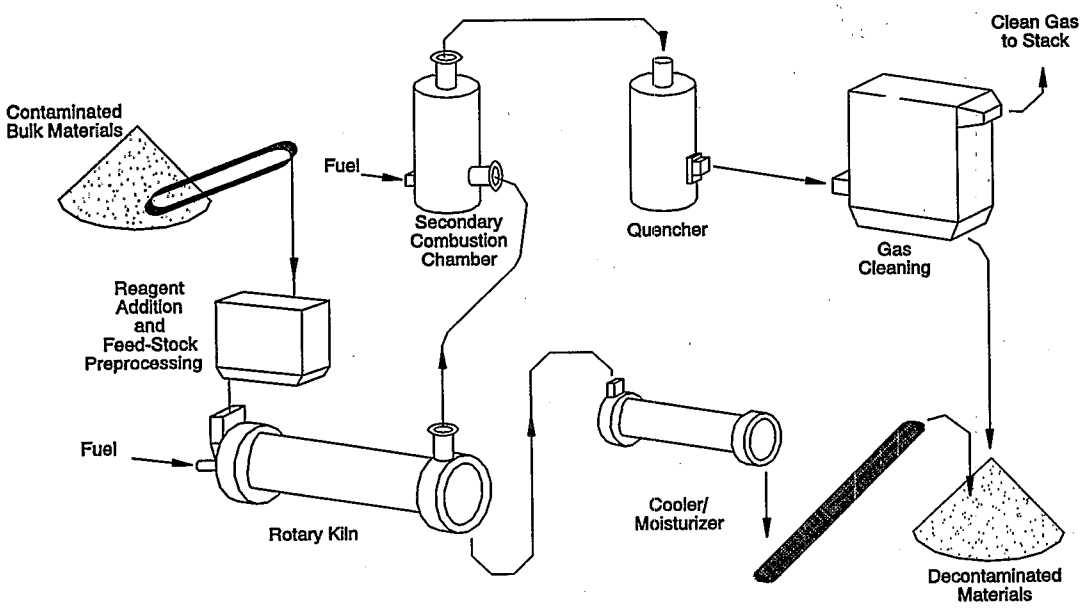
TECHNOLOGY DESCRIPTION:

The PYROKILN THERMAL ENCAPSULATION Process is designed to improve conventional rotary kiln hazardous waste incineration by introducing inorganic additives (fluxing agents) with the waste to promote incipient slagging or "thermal encapsulating" reactions near the kiln discharge end. The thermal encapsulation is augmented using other additives in either the kiln or in the air pollution control baghouse to stabilize the metals in the fly ash. The process is designed to thermally treat soils and sludges contaminated with both organics and metals. The advantages of this process include 1) immobilizing the metals remaining in the kiln ash, 2) producing an easily handled nodular form of ash, and 3) stabilizing metals in the fly ash, while avoiding the problems normally experienced with higher temperature "slagging kiln" operations (see figure below).

The basis of this process is thermal encapsulation. Thermal encapsulation traps metals in a controlled melting process operating in the temperature range between slagging and nonslagging modes, producing ash nodules that are 0.25 to 0.75 inch in diameter.

Wastes containing organic and metallic contaminants are incinerated in a rotary kiln. Metals (in particular, those with high melting points) are trapped in the bottom ash from the kiln through the use of fluxing agents that promote agglomeration with "controlled nodulizing."

The PYROKILN THERMAL ENCAPSULATION Process may reduce metals leaching to levels below EPA limits as proved by toxicity characteristic leaching procedure tests. Metals with low melting and vaporization temperatures, such as arsenic, lead, and zinc, are expected to partially volatilize, partitioning themselves between the bottom ash and the fly ash. Those that are concentrated in the fly ash may be stabilized, if necessary, by adding reagents to the kiln and to the air pollution control system to reduce metals leaching to below EPA limits.



PYROKILN THERMAL ENCAPSULATION Process

The SITE Program assesses but does not approve or endorse technologies.

This process may also reduce the total dust load to the air pollution control system and the amount of particulate emissions from the stack.

The use of fluxing reagents is a key element in this technology. The fluxing agents are introduced into the kiln in the proper amount and type to lower the ash's softening temperature. Proper kiln design is required to allow the kiln outlet to function as an ash agglomerator. Good temperature control is required to keep the agglomerates at the correct particle size, yielding the desired 0.25- to 0.75-inch nodules. By producing nodules, rather than a molten slag, the process is expected to prevent operating problems such as ash quenching, overheating, and premature refractory failure. The process should also simplify cooling, handling, and conveying of the ash.

The controlled nodulizing process should immobilize metals with high boiling points. Lead, zinc, and other metals with lower vaporization temperatures tend to leave the kiln as a fine fume and can be removed in the air pollution control system. Reagents can be injected into the kiln, the air pollution control devices, or a final solids mixer to stabilize fines collected from the gas stream.

WASTE APPLICABILITY:

The technology is intended for soils and sludges. As with other rotary kiln systems, the process is expected to destroy a broad range of organic species, including halogenated and nonhalogenated organics and petroleum products. Metallic compounds that may be encapsulated or stabilized include antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, and zinc.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in March 1990.

Allis Mineral System's Synthetic Soil, a synthetic soil matrix, was created for the batch rotary kiln tests. These tests yielded nodules with appropriate crush strength. Feed preparation was a key element in nodule production. A correlation was found of decreasing toxicity characteristic leaching procedure metal leachate levels with increasing crush strength.

An analytical procedure was selected that uses microwave-aided digestion to evaluate samples produced in a second batch kiln test program. This method provided excellent, consistent results, indicating leachability below EPA limits.

A final report has been prepared. A technical paper summarizing the project was presented at the Air and Waste Management Association 87th Annual Meeting and Exhibition in Cincinnati, Ohio, June 19-24, 1994.

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The SITE Program assesses but does not approve or endorse technologies.

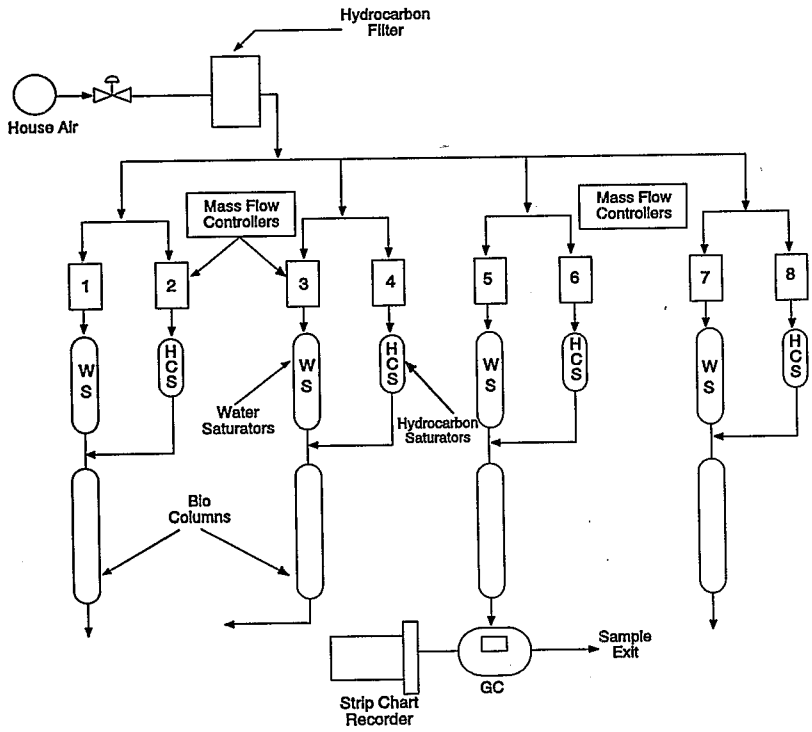
ALUMINUM COMPANY OF AMERICA (formerly ALCOA SEPARATION TECHNOLOGY, INC.) (Bioscrubber)

TECHNOLOGY DESCRIPTION:

This bioscrubber technology digests hazardous organic emissions generated by soil, water, and air decontamination processes. The bioscrubber consists of a filter with an activated carbon medium that supports microbial growth. This unique medium, with increased microbial population and enhanced bioactivity, converts diluted organics into carbon dioxide, water, and other nonhazardous compounds. The filter removes biomass, supplies nutrients, and adds moisture. A pilot-scale unit with a 4-cubic-foot-per-minute capacity is being field-tested (see figure below).

In addition to efficient degradation, the bioscrubber provides an effective sink to mitigate feed fluctuations. During an 11-month bench-scale test, the bioscrubber consistently removed contaminants such as petroleum hydrocarbons, alcohol, and keytone amines from the waste feed at levels ranging from less than 5 to 40 parts per million (ppm).

The bioscrubber provides several advantages over conventional activated carbon adsorbers. First, bioregeneration keeps the maximum adsorption capacity constantly available; thus, the mass transfer zone remains stationary and relatively short. The carbon does not require refrigeration and the required bed length is greatly reduced. These features reduce capital and operating expenses. The bioscrubber's advantages would be fully utilized when the off-gas contains weakly adsorbed contaminants, such as chromethylene chloride, or adsorbates competing with moisture in the stream. Finally the chromatographic effect (premature desorption)



Bioscrubber Pilot-Scale Unit

The SITE Program assesses but does not approve or endorse technologies.

common in an adsorber is eliminated because the maximum capacity is available constantly. The bioscrubber may replace activated carbon in some applications.

WASTE APPLICABILITY:

The bioscrubber technology removes organic contaminants in airstreams from soil, water, or air decontamination processes. The technology is especially suited to treat streams containing aromatic solvents, such as benzene, toluene, xylene, alcohols, ketones, hydrocarbons, and others. The technology will have a wide spectrum of applications to Superfund sites, including 1) organic emission control for groundwater decontamination using air strippers, 2) emission control for biological treatment of ground and surface water, and 3) emission control for soil decontamination. These primary treatment processes have not been designed to prevent volatile organic compound discharges into the atmosphere. The proposed technology is an ideal posttreatment for these processes because it handles trace organic volatiles economically and effectively.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1990. Bench-scale bioscrubbers operated continuously for more than 11 months to treat an air stream with trace concentrations of toluene at about 10 to 20 ppm. The bioscrubbers accomplished a removal efficiency of greater than 95 percent. The filter had a biodegradation efficiency 40 to 80 times greater than existing filters. The project was completed in June 1993.

Demonstration results have been published in the report "Bioscrubber for Removing Hazardous Organic Emissions from Soil, Water and Air Decontamination Processes" (EPA540/R-93/521). This report is available from the National Technical Information Service. Other reports available are the Technology Bulletin (EPA/540/F-93/507) and the Technology Summary (EPA/540/SR-93/521). An article was also published in the *Journal of Air and Waste Management*, Vol. 44, March 1994, pp. 299-303.

The pilot unit has been tested by treating 2 standard cubic feet per minute of discharge containing from less than 10 ppm up to 200 ppm toluene from an air stripping tower. The unit demonstrated the effectiveness, efficiency and reliability of its design. Additional tests are underway to confirm results at higher flow rates and with other contaminants.

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The SITE Program assesses but does not approve or endorse technologies.

ART INTERNATIONAL, INC.
(formerly ENVIRO-SCIENCES, INC.)
(Low-Energy Extraction Process)

TECHNOLOGY DESCRIPTION:

The patented Low-Energy Extraction Process (LEEP®) uses common organic solvents to concentrate and extract organic pollutants from soil, sediments, and sludges. LEEP® can treat contaminated solids to the stringent cleanup levels mandated by regulatory agencies. LEEP® includes pretreatment, washing, and concentration processes.

During pretreatment, particles measuring up to 8 inches in diameter are removed in a gravity settle-floater. The settler-floater includes a metal detector and remover, a crusher, and a metering feeder. Floating material often found at remediation sites, such as wood chips, grass, or root material, is also removed.

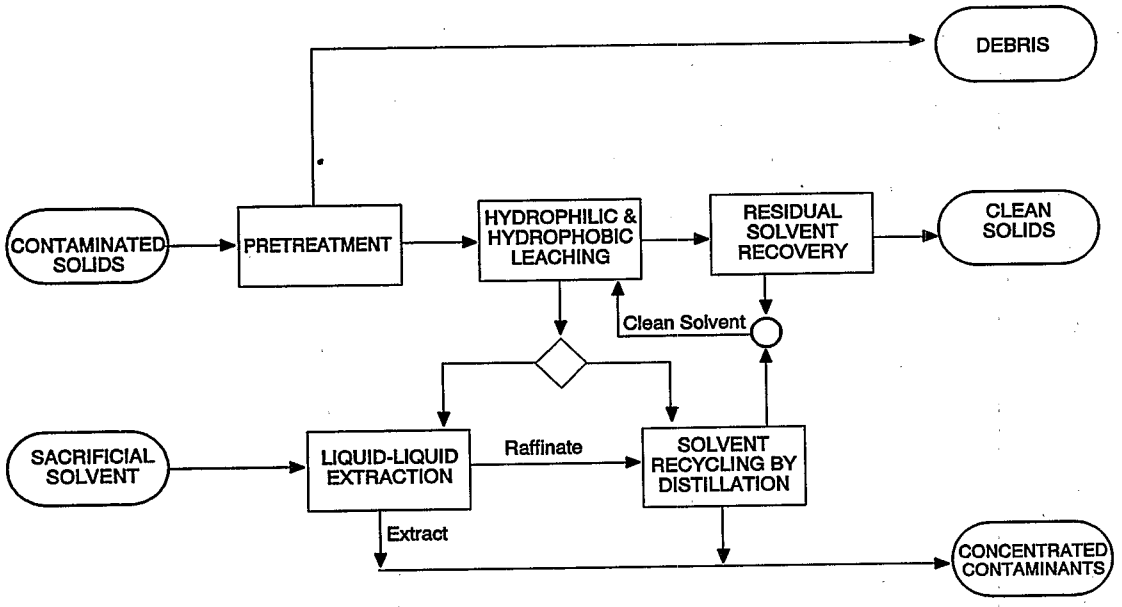
After pretreatment, the solid matrix is washed in a unique, dual solvent process that uses both hydrophilic and hydrophobic solvents. The combination of these proprietary solvents guarantees efficient contaminant removal.

The extracted pollutants are then concentrated in a sacrificial solvent by liquid-liquid extraction or by distillation, and are removed from the process for off-site disposal or recycling. The treated solids can be returned to the site as clean fill.

The LEEP® technology is a low-pressure process operated under a nitrogen blanket at near ambient conditions. It is designed as a closed-loop, self-contained, mobile unit consisting of proven heavy-duty equipment. The relatively inexpensive solvents used in the process are internally recycled. The solvents are applicable to almost every type of organic contaminant, and their physical properties enhance clay and silt particle settling.

WASTE APPLICABILITY:

LEEP® can treat most contaminants in soil, sediment, and sludge, including tar, creosote, chlorinated hydrocarbons, polynuclear aromatic hydrocarbons, pesticides, and wood preserving



LEEP® Technology Schematic

The SITE Program assesses but does not approve or endorse technologies.

chlorophenol formulations. Bench- and pilot-scale experiments have shown that LEEP® effectively treats tar-contaminated solids from manufactured gas plant sites, soils and sediments contaminated with polychlorinated biphenyls, refinery waste sludges, and soils contaminated with petroleum hydrocarbons.

STATUS:

LEEP® was accepted into the Emerging Technology Program in July 1989. Bench-scale studies for process development have been completed. In addition, ART International, Inc., routinely conducts bench-scale treatability studies for government and industrial clients, and has obtained Toxic Substances Control Act, Resource Conservation and Recovery Act, and air permits for the technology. Other developments include the following:

- Construction of a 200-pound-per-hour pilot plant
- Completion of pilot-plant tests indicated that LEEP® can treat soil from manufactured gas plant sites containing up to 5 percent tar
- Completion of pilot-plant tests for scaling up to a commercial plant
- Completion of commercial design criteria and a turnkey bid package
- Commercialization activities for a full-scale unit are underway

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The SITE Program assesses but does not approve or endorse technologies.

ATOMIC ENERGY OF CANADA, LIMITED
(Chemical Treatment and Ultrafiltration)

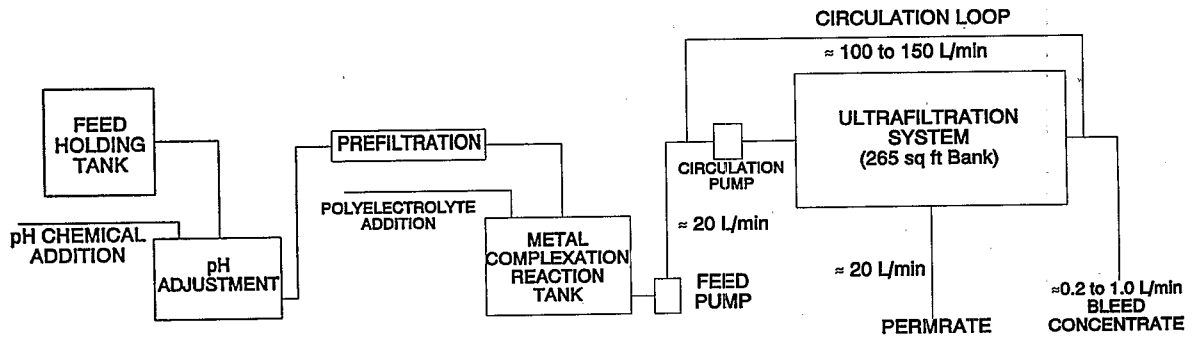
TECHNOLOGY DESCRIPTION:

The Atomic Energy of Canada, Limited (AECL), process uses chemical pretreatment and ultrafiltration to remove trace concentrations of dissolved metals from wastewater, contaminated groundwater, and leachate. The process selectively removes metal contaminants and produces a volume-reduced water stream for further treatment and disposal.

The installed unit's overall dimensions are 5 feet wide by 7 feet long by 6 feet high. The skid-mounted unit consists of 1) a bank of 5-micron cartridge prefilters, 2) a feed conditioning system with polyelectrolytes and chemicals for pH adjustment, 3) two banks of hollow-fiber ultrafilters, 4) a backflush system for cleaning the membrane unit, and 5) associated tanks and instrumentation.

Wastewater enters the prefilter through the feed tank, where suspended particles are removed from the feed. The filtered waste stream is then routed to conditioning tanks where the solution pH is adjusted. Water-soluble macromolecular compounds are then added to the wastewater to form complexes with heavy metal ions. Next, a relatively high molecular weight polymer, generally a commercially available polyelectrolyte, is added to the wastewater to form selective metal-polymer complexes at the desired pH and temperature. The necessary polyelectrolyte quantities depend on the metal ion concentration. Therefore, separated metal ions should generally be in the parts per million (ppm) range.

The treated waste stream then passes through a cross-flow ultrafiltration membrane system by way of a recirculation loop. The ultrafiltration system provides a total membrane surface area of 265 square feet and a permeate rate of about 6 gallons per minute (gpm). The membranes retain the metal complexes (concentrate), while allowing uncomplexed ions to pass through the membrane with the filtered water. The filtered water is continuously withdrawn, while the concentrate stream, containing most of the contaminants, is recycled through the recirculation loop until it meets the target concentration.



Single-Stage Chemical Treatment and Ultrafiltration Process

The SITE Program assesses but does not approve or endorse technologies.

After reaching the target concentration, the concentrate stream is withdrawn for further treatment, such as solidification. It can then be safely disposed of. The clean filtered water is discharged.

WASTE APPLICABILITY:

The process treats groundwater, leachate, and surface runoff water contaminated with trace levels of toxic heavy metals. The process also treats effluents from 1) industrial processes, 2) production and processing of base metals, 3) smelters, 4) electrolysis operations, and 5) battery manufacturing. Potential applications include removal of metals such as cadmium, lead, mercury, uranium, manganese, nickel, chromium, and silver.

The process can treat influent with dissolved metal concentrations from several ppm up to about 100 ppm. In addition, the process removes other inorganic and organic materials present as suspended or colloidal solids. The sole residue is the ultrafiltration concentrate, which generally constitutes 5 to 20 percent of the feed volume.

STATUS:

The AECL process was accepted into the SITE Program in 1988. During initial bench-scale and pilot-scale tests, the AECL process successfully removed cadmium, lead, and mercury. These results were used to design and construct the mobile unit.

The mobile unit has been tested at the Chalk River Laboratories and a uranium mine tailings site in Ontario, Canada. The field demonstration indicated that process water characteristics needed further study; pretreatment schemes are being evaluated. The mobile unit, which is capable of treating influent flows ranging from 1,000 to 5,000 gallons per day, is available for treatability tests and on-site applications. A technology bulletin (EPA/540/F-92/002) is available.

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The SITE Program assesses but does not approve or endorse technologies.

BABCOCK & WILCOX CO.
(Cyclone Furnace)

TECHNOLOGY DESCRIPTION:

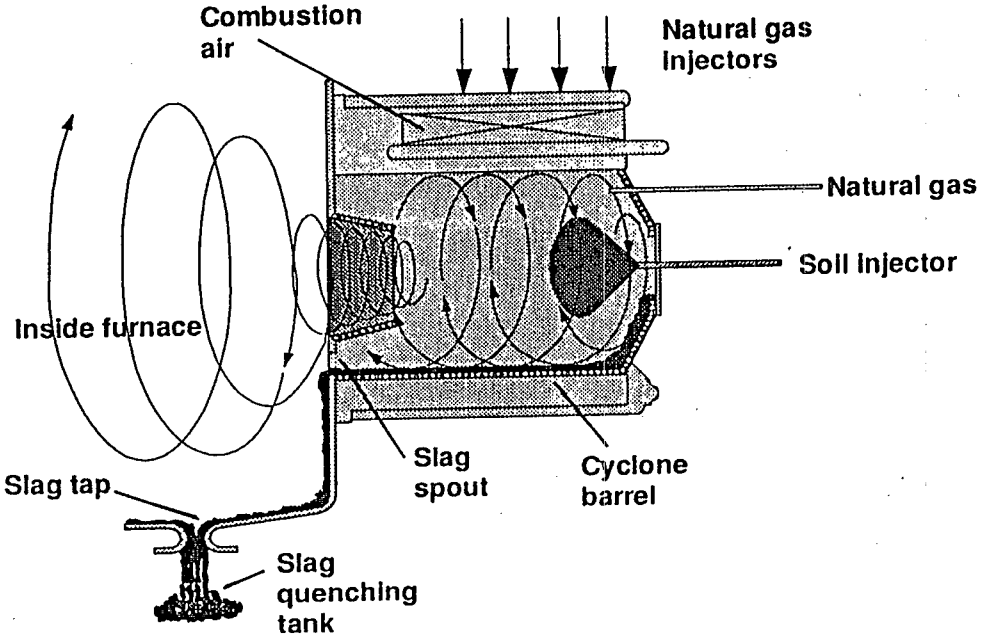
The Babcock & Wilcox Co. (Babcock & Wilcox) cyclone furnace is designed to combust high inorganic (high-ash) coal. Through cofiring, the cyclone furnace can also accommodate highly contaminated wastes containing heavy metals and organics in soil or sludge. High heat-release rates of 45,000 British thermal units (Btu) per foot of coal ensure the high temperatures required to melt the high-ash fuels. The inert ash exits the cyclone furnace as a vitrified slag.

The furnace is water-cooled and simulates the geometry of Babcock & Wilcox's single-cyclone, front-wall-fired cyclone boilers. The pilot cyclone furnace, shown in the figure below, is a scaled-down version of a commercial coal-fired cyclone with a restricted exit (throat). The furnace geometry is a horizontal cylinder (barrel).

Natural gas and preheated combustion air are heated to 820 degrees Fahrenheit (°F) and enter tangentially into the cyclone burner. For dry soil processing, the soil matrix and natural gas enter tangentially along the cyclone furnace barrel. For wet soil processing, an atomizer uses compressed air to spray the soil paste directly into the furnace. The soil or sludge and inorganics are captured and melted, and organics are destroyed in the gas phase or in the molten slag layer. This slag layer is formed and retained on the furnace barrel wall by centrifugal action.

The soil melts, exits the cyclone furnace from the tap at the cyclone throat, and drops into a water-filled slag tank where it solidifies. A small quantity of soil also exits as fly ash with the flue gas from the furnace and is collected in a baghouse. In principle, this fly ash can be recycled to the furnace to increase the capture of metals, and to minimize the volume of the potentially hazardous waste stream.

The energy requirements for vitrification are 15,000 Btu/pound (lb) of soil treated. Given the much larger surface-to-volume ratio of the relatively small pilot unit and its cool surface, a full-scale unit can be expected to have propor-



Cyclone Furnace

The SITE Program assesses but does not approve or endorse technologies.

tionally lower energy requirements. The cyclone furnace can be operated with gas, oil, or coal as the supplemental fuel. The waste may also supply a significant portion of the required heat input.

Particulates are controlled by a baghouse. To maximize the capture of metals, a heat exchanger is used to cool the stack gases to approximately 200 °F before they enter the baghouse.

WASTE APPLICABILITY:

The cyclone vitrification technology is applicable to highly contaminated inorganic hazardous wastes, sludges, and soils that contain heavy metals and organic constituents. The wastes may be solid, a soil slurry (wet soil), or liquid. To be treated in the cyclone furnace, the ash or solid matrix must melt (with or without additives) and flow at cyclone furnace temperatures (2,400 to 3,000 °F). Because of the technology's ability to capture heavy metals in the slag and render them nonleachable, the technology is an important treatment application for soils that contain lower-volatility radionuclides such as strontium and transuranics.

STATUS:

The 6-million-Btu/hour (hr) cyclone furnace was successfully used in a 2-year SITE Emerging Technology Program project to melt and vitrify an EPA-supplied synthetic soil matrix (SSM) spiked with 7,000 parts per million (ppm) lead, 1,000 ppm cadmium, and 1,500 ppm chromium. In addition to destroying organic wastes, vitrification products capture and do not leach heavy metals; other thermal treatments do. When operated at 50 to 150 pounds per hour (lb/hr) of dry SSM feed and 100 to 300 lb/hr of wet SSM feed, the cyclone furnace produced a nonleachable product (as measured by the toxicity characteristic leaching procedure) for lead, cadmium, and chromium.

From 95 to 97 percent of the dry SSM was incorporated within the slag. Cyclone operation stabilized during the two projects, and processed over 6 tons of clean, unspiked SSM and 5 tons of spiked SSM. During the thermal vitrification process, the heavy metals partitioned between the vitrified slag and the stack fly ash. Retained metal percentages for vitrified slag at 200 lb/hr were 12 to 23 percent for cadmium, 38 to 54 percent for lead, and 78 to 95 percent for chromium. Heavy metal captured in the slag increased with feed rate and decreased with metal volatility.

These results suggest that the cyclone vitrification process will show a high capture rate for very low volatility contaminants, such as many radionuclides (for example, uranium and thorium). The SSM treatment resulted in a dry volume reduction of 25 to 35 percent. Vitrification yields in an easily-crushed, glassy product.

EPA has published a bulletin (EPA/540/F-92/010), a final report (EPA/540/R-93/501), and a summary (EPA/540/SR-93/507) detailing results from this project.

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The SITE Program assesses but does not approve or endorse technologies.

BATTELLE MEMORIAL INSTITUTE
(In Situ Electroacoustic Soil Decontamination)

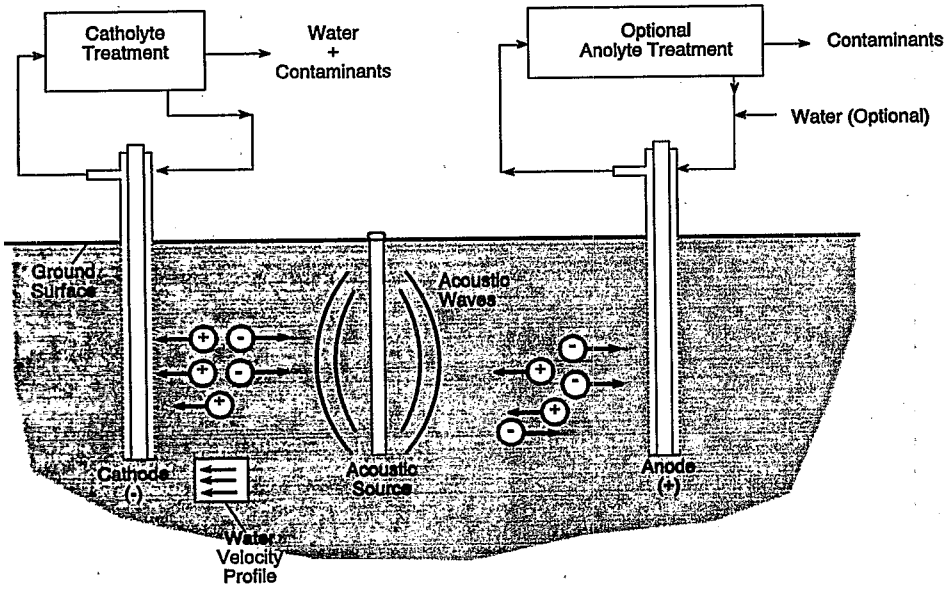
TECHNOLOGY DESCRIPTION:

The patented in situ electroacoustic soil decontamination (ESD) technology treats soils containing hazardous organics by applying direct current electrical and acoustic fields. Direct current facilitates liquid transport through soils. The technology consists of electrodes, an anode and a cathode, and an acoustic source (see figure below).

The double-layer boundary theory is important when an electric potential is applied to soils. For soil particles, the double layer consists of a fixed layer of negative ions that are firmly held to the solid phase, and a diffuse layer of cations and anions that are more loosely held. Applying an electric potential to the double layer displaces the loosely held ions to their respective electrodes. The cations take water with them as they move toward the cathode.

Besides ESD water transport through wet soils, the direct current produces other effects, such as ion transfer, pH gradients development, electrolysis, oxidation and reduction, and heat generation. Heavy metals present in contaminated soils can be leached or precipitated out of solution by electrolysis, oxidation and reduction reactions, or ionic migration. The soil contaminants may be 1) cations, such as cadmium, chromium, and lead; or 2) anions, such as cyanide, chromate, and dichromate. The existence of these ions in their respective oxidation states depends on soil pH and concentration gradients. Direct current is expected to increase the leaching rate and precipitate the heavy metals out of solution by establishing appropriate pH and osmotic gradients.

When properly applied in conjunction with an electric field and water flow, an acoustic field can enhance waste dewatering or leaching. This phenomenon is not fully understood. Another possible application involves unclogging recovery wells. Since contaminated particles are driven to the recovery well, the pores and interstitial spaces in the soil can close. This



In Situ Electroacoustic Soil Decontamination (ESD) Process

The SITE Program assesses but does not approve or endorse technologies.

technology could be used to clear these clogged spaces.

WASTE APPLICABILITY:

The technology's potential for improving non-aqueous phase liquid contaminant recovery and in situ removal of heavy metals needs to be tested on a pilot scale using clay soils.

STATUS:

Phase I results indicate that ESD is technically feasible to remove inorganic species such as zinc and cadmium from clay soils, and only marginally effective for hydrocarbon removal. A modified ESD process for more effective hydrocarbon removal has been developed but not tested. An EPA report (EPA/540/5-90/004) for the 1-year investigation can be purchased through the National Technical Information Service, document No. PB 90-204 728/AS. A summary (EPA/540/S5-90/004) is also available.

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The SITE Program assesses but does not approve or endorse technologies.

BIO-RECOVERY SYSTEMS, INC.
(Biological Sorption)

TECHNOLOGY DESCRIPTION:

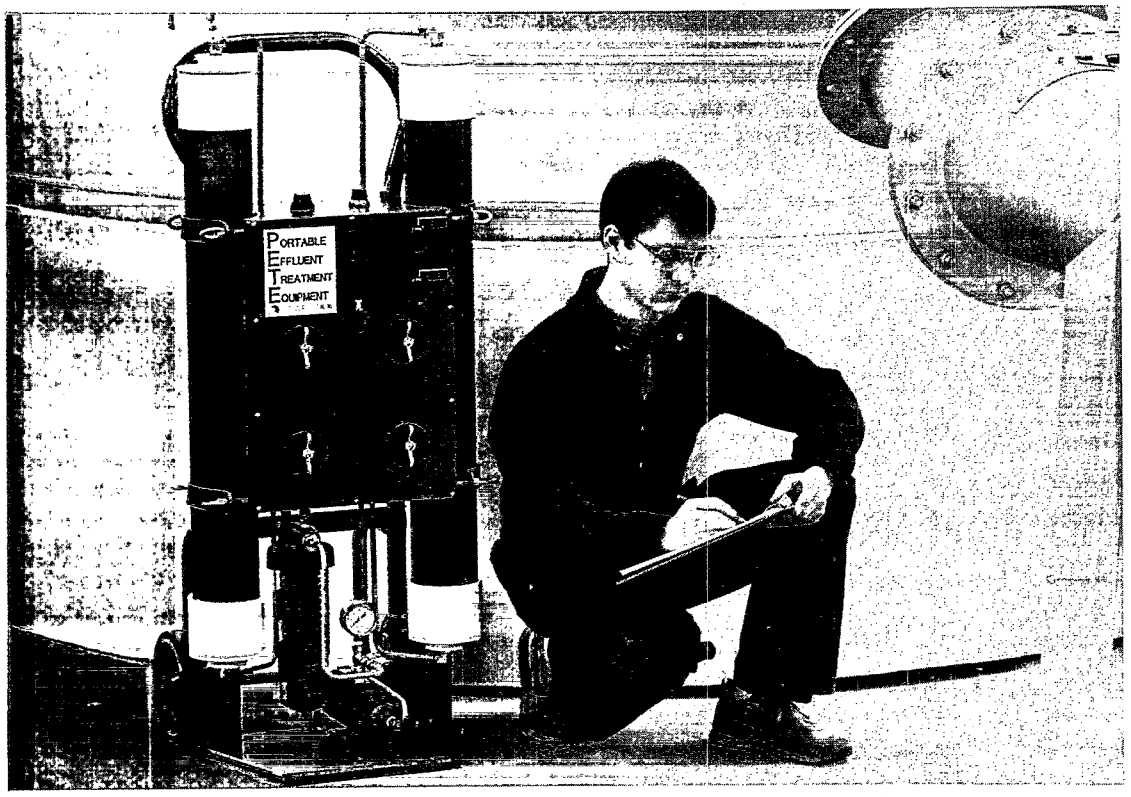
The AlgaSORB© sorption process uses algae to remove heavy metal ions from aqueous solutions. The process takes advantage of the natural affinity for heavy metal ions exhibited by algal cell structures.

The photograph below shows a prototype portable effluent treatment equipment (PETE) unit, consisting of two columns operating in series or in parallel. Each column contains 0.25 cubic foot of AlgaSORB©, the treatment matrix. The PETE unit shown below can treat waste at a flow rate of approximately 1 gallon per minute (gpm). Larger systems have been designed and manufactured to treat waste at flow rates greater than 100 gpm.

The AlgaSORB© medium consists of dead algal cells immobilized in a silica gel polymer. This immobilization serves two purposes: 1) it protects the algal cells from decomposition by other microorganisms, and 2) it produces a hard material that can be packed into chromatographic columns that, when pressurized, still exhibit good flow characteristics.

The system functions as a biological ion-exchange resin to bind both metallic cations (positively charged ions, such as mercury, Hg^{+2}) and metallic oxoanions (negatively charged, large, complex, oxygen-containing ions, such as selenium oxide [SeO_4^{-2}]). Anions such as chlorides or sulfates are only weakly bound or not bound at all.

Like ion-exchange resins, the algae-silica system can be recycled. However, in contrast to current ion-exchange technology, divalent cations typical of hard water, such as calcium (Ca^{+2}) and magnesium (Mg^{+2}), or monovalent cations,



Portable Effluent Treatment Equipment (PETE) Unit

The SITE Program assesses but does not approve or endorse technologies.

such as sodium (Na^+) and potassium (K^+), do not significantly interfere with the binding of toxic heavy metal ions to the algae-silica matrix.

After the matrix is saturated, the metals are stripped from the algae with acids, bases, or other suitable reagents. This stripping process generates a small volume of solution containing highly concentrated metals that must undergo treatment.

WASTE APPLICABILITY:

This technology can remove metal ions from groundwater or surface leachates that are "hard" or contain high levels of dissolved solids. The process can also treat rinse waters from electroplating, metal finishing, and printed circuit board manufacturing industries.

The system can remove heavy metals, such as aluminum, cadmium, chromium, cobalt, copper, gold, iron, lead, manganese, mercury, molybdenum, nickel, platinum, silver, uranium, vanadium, and zinc.

STATUS:

Under the Emerging Technology Program, the AlgaSORB© sorption process was tested on mercury-contaminated groundwater at a hazardous waste site in Oakland, California, in fall 1989. Testing was designed to determine optimum flow rates, binding capacities, and the efficiency of stripping agents. The Final Report (EPA/540/5-90/005a), a Summary (EPA/540/S5-90/005), and a Bulletin (EPA/540/F-92/003) are available from EPA. An article was also published in the *Journal of Air and Waste Management*, Vol. 41, No. 10, October 1991. Based on results from the Emerging Technology Program, Bio-Recovery Systems, Inc., was invited to participate in the SITE Demonstration Program. A suitable site is being sought.

The process is being commercialized for groundwater treatment and industrial point source treatment.

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The SITE Program assesses but does not approve or endorse technologies.

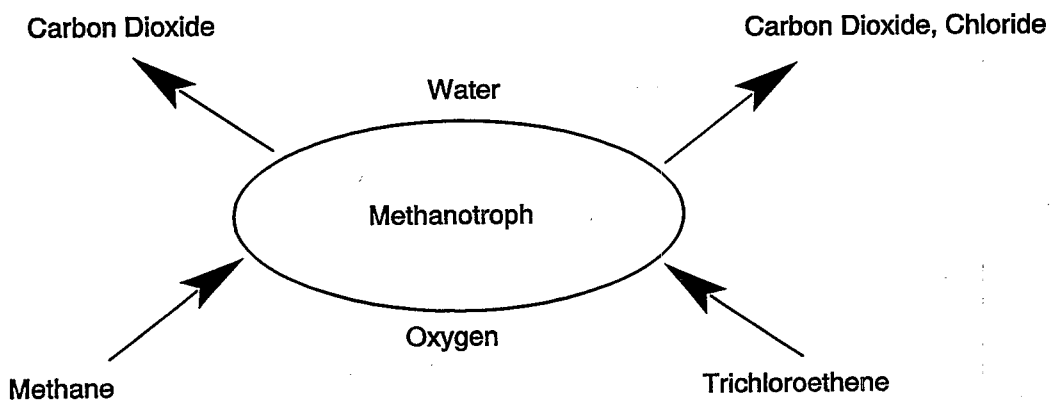
BIOTROL, INC.
(Methanotrophic Bioreactor System)

TECHNOLOGY DESCRIPTION:

The methanotrophic bioreactor system is an aboveground remedial technology for water contaminated with halogenated hydrocarbons. Trichloroethene (TCE) and related compounds pose a new and difficult challenge to biological treatment. Unlike aromatic hydrocarbons, for example, TCE cannot serve as a primary substrate for bacterial growth. Degradation depends on cometabolism, which is attributed to the broad substrate specificity of certain bacterial enzyme systems (see figure below). Although many aerobic enzyme systems reportedly cooxidize TCE and related compounds, BioTrol, Inc. (BioTrol), claims that the methane monooxygenase (MMO) of methanotrophic bacteria is the most promising.

Methanotrophs are bacteria that can use methane as a sole source of carbon and energy. Although certain methanotrophs can express MMO in either a soluble or particulate (membrane-bound) form, BioTrol-sponsored research has discovered that the soluble form induces extremely rapid TCE degradation rates. Two patents have been obtained and an additional patent is pending on the process.

BioTrol has also developed a colorimetric assay that verifies the desired enzyme's presence in the bioreactor culture. Results from experiments with *Methylosinus trichosporium* OB3b indicate that the maximum specific TCE degradation rate is 1.3 grams of TCE per gram of cells (dry weight) per hour, which is 100 to 1,000 times faster than reported TCE degradation rates for nonmethanotrophs. This species of methanotrophic bacteria reportedly removes various chlorinated aliphatic compounds by more than 99.9 percent.



Cometabolism of TCE

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The bioreactor system can treat water contaminated with halogenated aliphatic hydrocarbons, including TCE, dichloroethene isomers, vinyl chloride, dichloroethane isomers, chloroform, dichloromethane (methylene chloride), and others. In the case of groundwater treatment, bioreactor effluent can either be reinjected or discharged to a sanitary sewer or a National Pollutant Discharge Elimination System.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1990. Both bench- and pilot-scale tests were conducted using a continuous-flow, dispersed-growth system. As shown in the figure below, the pilot-scale reactor displayed first-order TCE degradation kinetics. An article on the pilot-scale demonstration is expected to appear in the *Journal of the Air and Waste Management Association* in late 1994. A Technology Bulletin (EPA/540/F-93/506) and a Technology Summary (EPA/540/SR-93/505) are available from EPA.

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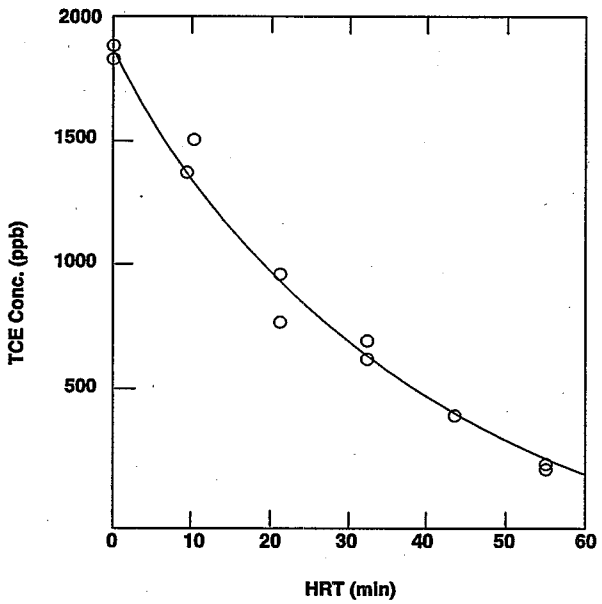


Pilot-Scale Continuous-Flow Results

The SITE Program assesses but does not approve or endorse technologies.

CENTER FOR HAZARDOUS MATERIALS RESEARCH
(Acid Extraction Treatment System)

TECHNOLOGY DESCRIPTION:

The acid extraction treatment system (AETS) uses hydrochloric acid to extract heavy metal contaminants from soils. Following treatment, the clean soil may be returned to the site or used as fill.

A simplified block flow diagram of the AETS is given in the figure below. First, soils are screened to remove coarse solids. These solids, typically greater than 4 millimeters in size, are relatively clean and require at most a simple rinse with water or detergent to remove smaller attached particles.

After coarse particle removal, the remaining soil is scrubbed in an attrition scrubber to break up agglomerates and cleanse surfaces. Hydrochloric acid is then introduced into the soil in the extraction unit. The residence time in the unit varies depending on the soil type, contaminants, and contaminant concentrations, but generally ranges between 10 and 40 minutes. The soil-extractant mixture is continuously pumped out of the mixing tank, and the soil and extractant are separated using hydrocyclones.

When extraction is complete, the solids are transferred to the rinse system. The soils are rinsed with water to remove entrained acid and metals. The extraction solution and rinsewaters are regenerated using a proprietary technology that removes the metals and reforms the acid.

The heavy metals are concentrated in a form potentially suitable for recovery. During the final step, the soils are mixed with lime and fertilizer to neutralize any residual acid. No wastewater streams are generated by the process.

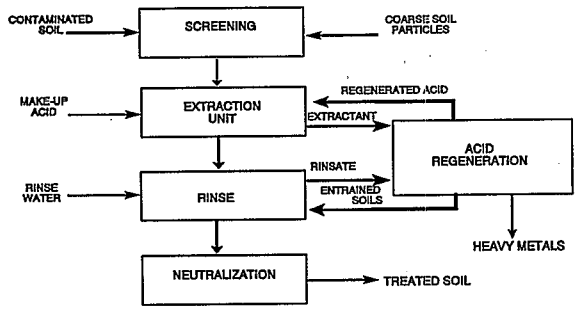
WASTE APPLICABILITY:

The main application of AETS is extraction of heavy metals from soils. The system has been tested using a variety of soils, containing one or more of the following: arsenic, cadmium, chromium, copper, lead, nickel, and zinc. The treatment capacity is expected to range up to 30 tons per hour. AETS can treat all soil fractions, including fines.

The major residuals from AETS treatment include the cleaned soil, which is suitable for fill or for return to the site, and the heavy metal concentrate. Depending on the concentration of heavy metals, the mixtures of heavy metals found at the site, and the presence of other compounds (calcium, sodium) with the metals, heavy metals may be reclaimed from the concentrate.

STATUS:

Under the Emerging Technology Program, laboratory-scale and bench-scale tests were conducted to develop the AETS technology. The bench-scale pilot system was constructed to process between 20 and 100 kilograms of soil per hour.



Acid Extraction Treatment System (AETS) Process

The SITE Program assesses but does not approve or endorse technologies.

Five soils were tested, including an EPA synthetic soil matrix (SSM), and soils from four Superfund sites, including NL Industries in Pedricktown, New Jersey; King of Prussia site in Winslow Township, New Jersey; a smelter site in Butte, Montana; and Palmerton Zinc site in Palmerton, Pennsylvania. These soils contained elevated concentrations of some or all of the following: arsenic, cadmium, chromium, copper, lead, nickel, and zinc. The table below summarizes soil treatability results based on the EPA Resource Conservation and Recovery Act (RCRA) hazardous waste requirements for toxicity characteristic leaching procedure (TCLP) and the California standards for total metal concentrations. Detailed results from the study have been published by EPA in a Final Report (EPA/540/R-94/513) and a Summary (EPA/540/SR-94/513).

The results of the study are summarized below:

- AETS can treat a wide range of soils containing a wide range of heavy metals to reduce the TCLP below the RCRA limit. AETS can also reduce the total metals concentrations below the California-mandated total metals limitations.
- In most cases, AETS can treat the entire soil, without separate stabilization and disposal for fines or clay particles, to the required TCLP and total metal limits. The only exception was the SSM, which may require separate stabilization and disposal of 20 percent of the soil to reduce the total TCLP lead concentrations appropriately. However, AETS successfully treated arsenic, cadmium, chromium, copper, nickel, and zinc in the soil.
- Treatment costs under expected process conditions range from $100 to $180 per cubic yard of soil, depending on the site size, soil types and contaminant concentrations. Operating costs ranged from $50 to $80 per cubic yard. These costs are competitive with alternative technologies.

The Center for Hazardous Materials Research is looking for additional partners interested in finding a suitable site to demonstrate the technology.

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	Soil				
Metal	SSM	Butte	King of Prussia	Pedricktown	Palmerton
As	*, T, L	*, T, L			
Cd	*, T				*, T, L
Cr	*, T, L		***, T, L**	*, T, L	
Cu	***, T, L**	*, T, L	*, T, L		*, T, L
Ni	*, T, L		*, T, L		
Pb	*	*, T, L		***, T, L**	*, T, L
Zn	***, T, L**	*, T, L		*, T, L	*, T, L

Key: * -- Metal is present in that soil
T -- Successful treatment for total metals
L -- Reduction in leachability to below standards

Boldface and larger fonts indicate high initial metals concentration (at least double the regulatory standards)

The SITE Program assesses but does not approve or endorse technologies.

CENTER FOR HAZARDOUS MATERIALS RESEARCH
(Smelting Lead-Containing Waste)

TECHNOLOGY DESCRIPTION:

Secondary lead smelting is a proven technology that reclaims lead from lead-acid battery waste sites. The Center for Hazardous Materials Research (CHMR) and Exide Corporation (Exide) have demonstrated the use of secondary lead smelting to reclaim usable lead from various types of waste materials.

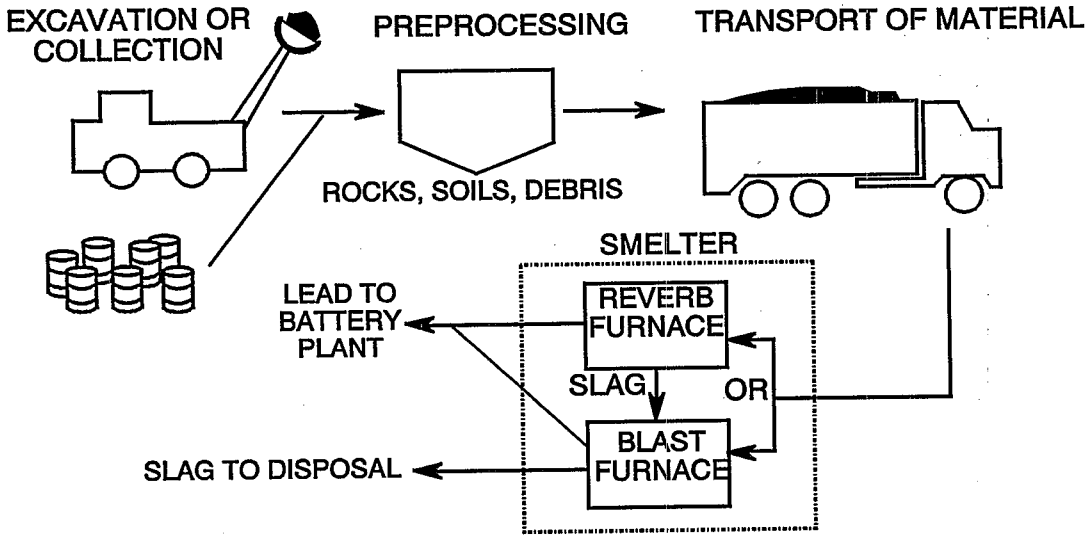
Reclamation of lead from Superfund and other lead-containing sites is based on existing lead smelting procedures and basic pyrometallurgy. A general schematic for the technology is provided in the figure below. Waste material is first excavated from Superfund sites or collected from other sources. The waste is then preprocessed to reduce particle size and to remove rocks, soil, and other debris. Next, the waste is transported to the smelter.

At the smelter, waste is fed to reverberatory or blast furnaces, depending on particle size or lead content. The two reverberatory furnaces normally treat lead from waste lead-acid batteries, as well as other lead-containing material. The furnaces are periodically tapped to remove slag, which contains 60 to 70 percent lead, and a soft pure lead product.

The two blast furnaces treat slag generated from the reverberatory furnaces, as well as larger-sized lead-containing waste. These furnaces are tapped continuously for lead and tapped intermittently to remove slag, which is transported off-site for disposal. The reverberatory and blast furnace combination at Exide can reclaim lead from batteries and waste with greater than 99 percent efficiency.

WASTE APPLICABILITY:

The process has been demonstrated to reclaim lead from a variety of solid materials, including rubber battery case material, lead dross, iron shot abrasive blasting material, and wood from demolition of houses coated with lead paint. The technology is applicable to solid wastes containing more than 2 percent lead, provided that they do not contain excessive amounts of calcium, silica, aluminum, or other similar constituents. Explosive and flammable liquids cannot be processed in the furnace. As tested, this technology is not applicable to soil remediation.



Smelting Lead-Containing Waste Process

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1991. Field work for the project was completed in February 1993. Reports are available for many of the demonstrations, and CHMR is completing the final technology report. An article about the technology will be published by the *Journal of Hazardous Materials* in fall 1994.

The process was tested at three Superfund sites. Materials obtained from two additional sites were also used for these tests.

Results from the Emerging Technology Program, presented in the table below, show that the process is applicable to waste materials at each site and economically feasible for all but the demolition material from the Laurel House site.

Specific technical problems encountered included 1) loss of furnace production due to material buildup within the furnaces, 2) breakdowns in the feed system due to mechanical overloads, and 3) increased oxygen demands inside the furnaces. All of these problems were solved by adjusting material feed rates or furnace parameters.

Based on these tests, CHMR has concluded that secondary lead smelting is an economical method of reclaiming lead from lead-containing waste material collected at Superfund sites and other sources.

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Source of Material Type of Material Tested	% Lead	Economical*	Test Results
Tonolli Superfund site (PA) Battery Cases	3 to 7	Yes	Lead can be reclaimed in secondary lead smelter. Incorporate into regular blast furnace feed stock.
Hebalka Superfund Site (PA) Battery Cases	10	Yes	Lead can be reclaimed in secondary lead smelter. Reduce in size and incorporate into regular reverberatory furnace feed stock.
Pedricktown Superfund Site (NJ) Battery Cases; lead containing dross, residue and debris	45	Yes	Lead can be reclaimed in secondary lead smelter. Screen and incorporate into regular reverberatory and blast furnace feed stocks.
Laurel House Women's Shelter (PA) Demolition material contaminated with lead-based paint.	1	No	Lead can be reclaimed in secondary lead smelter. However, the cost of processing the material was estimated to be very high.
PennDOT Abrasive Bridge Blasting Material	3 to 5	Yes	Lead can be reclaimed in secondary lead smelter. Incorporate into regular blast furnace feed stock.

* Economical compared to stabilization or landfilling.

Results from Field Tests of the Smelting Lead-Containing Waste Technology

The SITE Program assesses but does not approve or endorse technologies.

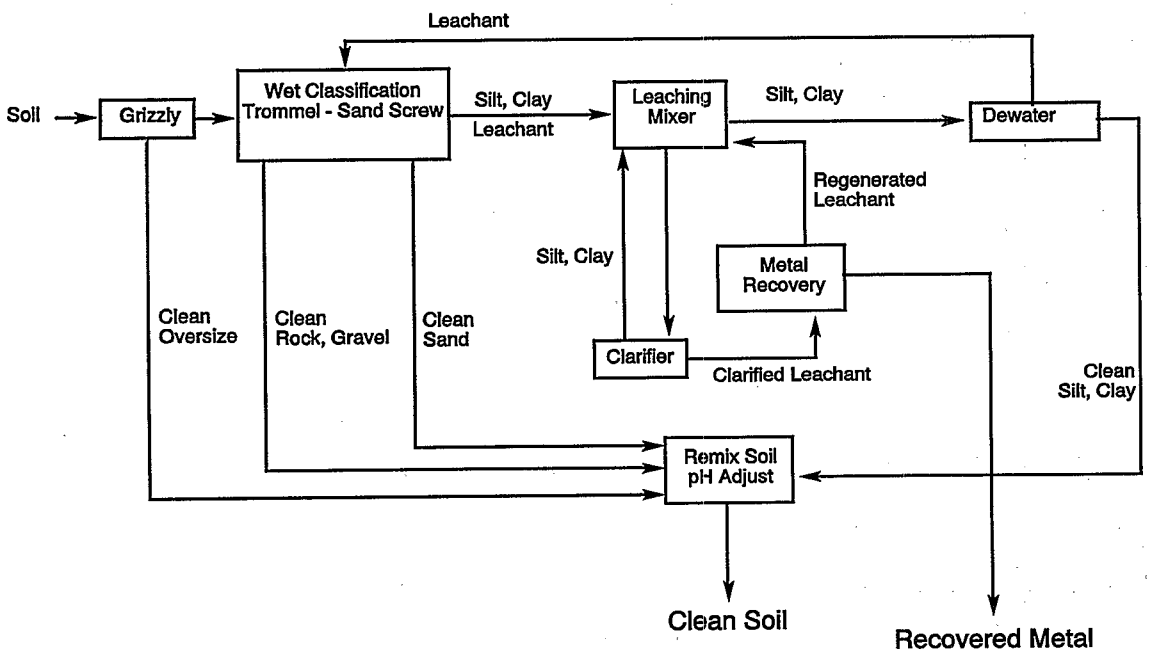
COGNIS, INC.
(Chemical Treatment)

TECHNOLOGY DESCRIPTION:

The COGNIS, Inc. (COGNIS), TERRAMET® soil remediation system leaches and recovers lead and other metals from contaminated soil, dust, sludge, or sediment. The system uses a proprietary aqueous leachant that is optimized through treatability tests for the soil and the contaminant. The TERRAMET® system can treat most types of lead contamination, including metallic lead, soluble ions, and insoluble lead oxides and salts. These contaminants are often tightly bound by fine soil constituents such as clay, manganese, iron oxides, and humus.

During the first processing stage, dry screening removes oversized material. Next, solids are separated by wet particle size classification. If the contamination resides in the soil fines (silt, clay, and humus), gravel and sand are quickly cleaned and separated from the fines, which require different leaching conditions to remove the metals. A fines-only leaching example is illustrated in the figure below. When the contamination is distributed throughout the soil fractions, all of the soil is leached.

After the lead contaminants are dissolved, lead ions are recovered from the aqueous leachate by liquid ion exchange, resin ion exchange, or reduction. The aqueous leaching solution can then be reused. If a liquid or resin ion exchange agent is used, it is stripped of the bound lead, fully regenerated, and recycled. The lead is recovered in concentrated form as solid metal or a metal salt suitable for recycling. The lead recovery method depends on the lead concentration and other metals present.



TERRAMET® Lead Removal Process (Fines Leaching Example)

The SITE Program assesses but does not approve or endorse technologies.

Important characteristics of the leachant and extractant combination are as follows:

- The leachant is tailored to the substrate and the contaminant
- The leachant is fully reusable
- Leachant materials are readily available
- The process uses commercially proven metals recovery techniques

WASTE APPLICABILITY:

The COGNIS TERRAMET® metals leaching system can treat soil, sediment, and sludge contaminated with lead and other heavy metals, or metal mixtures. Appropriate sites include contaminated battery recycling centers, scrapyards, metal plating shops, and chemical manufacturing facilities. The system can treat metallic lead as well as soluble and insoluble salts and oxides. Certain lead compounds, such as lead sulfide, are not amenable to treatment. The process can be modified to leach and recover other metals, such as cadmium, zinc, copper, and mercury. End products include clean soil and recycled metal or metal salts. No wastewater streams are generated.

STATUS:

The COGNIS TERRAMET® metals leaching system was accepted into the SITE Emerging Technology Program in August 1992. COGNIS conducted bench-scale testing to enter the SITE Demonstration Program, and pilot-scale equipment has been assembled that will treat 250 kilograms of soil per batch. To date, lead-contaminated soil samples at concentrations of 17,000 parts per million (ppm) have been treated to less than 300 ppm residual lead. The system has also removed metals to below background concentrations; for example, from greater than 400 ppm lead to less than 8 ppm lead. Bench-scale leaching has been conducted with several samples from state Superfund sites. Reports detailing study results are underway. A full-scale unit was constructed and operated at Twin Cities Army Ammunition Plant, New Brighton, Minnesota. For further information on the full-scale system, see the profile in the Demonstration Section (completed projects).

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The SITE Program assesses but does not approve or endorse technologies.

COLORADO SCHOOL OF MINES
(Constructed Wetlands-Based Treatment)

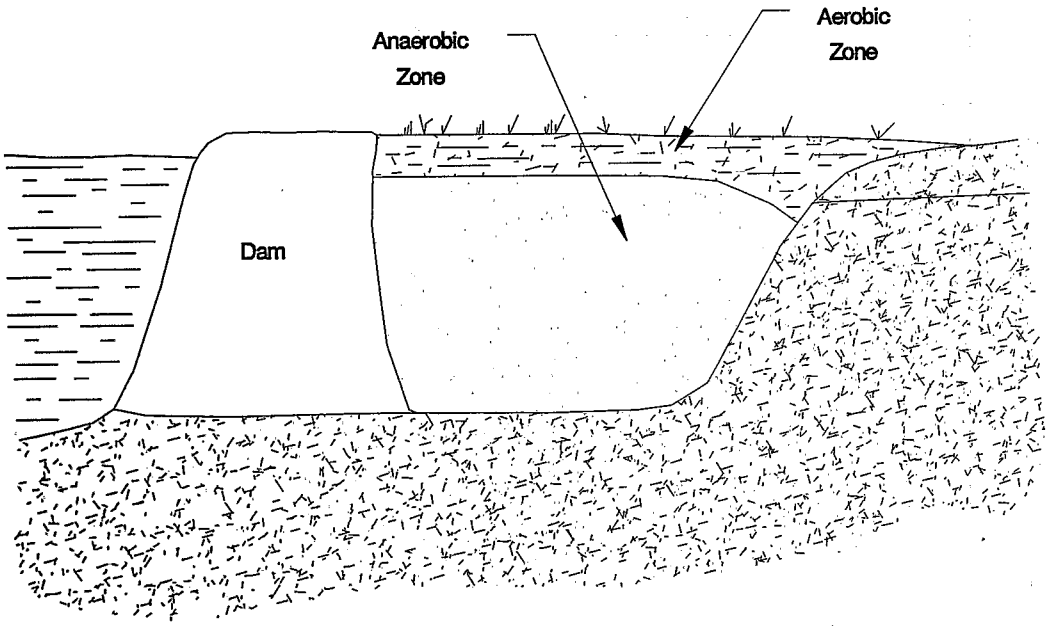
TECHNOLOGY DESCRIPTION:

The constructed wetlands-based treatment technology uses natural geochemical and biological processes inherent in an artificial wetland ecosystem to accumulate and remove metals and other contaminants from influent waters (see figure below). Although these treatment systems incorporate principal ecosystem components found in wetlands, including organic soils, microbial fauna, algae, and vascular plants, microbial activity is responsible for most of the remediation.

Influent waters with high metal concentrations and low pH flow through the aerobic and anaerobic zones of the wetland ecosystem. Metals are removed through ion exchange, adsorption, absorption, and precipitation with geochemical and microbial oxidation and reduction. Ion exchange occurs as metals in the water contact humic or other organic substances in the soil medium. Oxidation and reduction reactions catalyzed by bacteria that occur in the aerobic and anaerobic zones, respectively, play a major role in precipitating metals as hydroxides and sulfides. Precipitated and adsorbed metals settle in quiescent ponds or are filtered out as water percolates through the soil or the plant substrate.

WASTE APPLICABILITY:

The wetlands-based treatment process has been developed for acid mine drainage generated by metal or coal mining activities. These wastes typically contain high metals concentrations and are acidic. The process can be adapted to treat neutral and basic tailings solutions. Wetlands treatment has been applied with some success to wastewater in the eastern United States. The process has been adjusted to account for differences in geology, terrain, trace metal composition, and climate in the metal mining regions of the western United States.



Typical Wetland Ecosystem

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

Based on the results from the SITE Emerging Technology Program, this process has been selected to participate in the SITE Demonstration Technology. The final year of funding for the project under the Emerging Technology Program was completed in 1991. The funding was used to build, operate, monitor, and assess the effectiveness of a constructed wetlands in treating a portion of acid mine drainage from the Big Five Tunnel site near Idaho Springs, Colorado. A final report (EPA/540/R-93/523), a Summary (EPA/540/SR-92/523), and a Bulletin (EPA/540/F-92/001) are available.

Study results indicated that heavy metal removal efficiency can approach the removal efficiency of chemical precipitation treatment plants. Some of the optimum results from the 3 years of operation are listed below.

- pH was raised from 2.9 to 6.5
- Dissolved aluminum, cadmium, chromium, copper, and zinc concentrations were reduced by 99 percent or more
- Iron was reduced by 99 percent
- Lead was reduced by 94 percent or more
- Nickel was reduced by 84 percent or more
- Manganese removal was relatively low, with reduction between 9 and 44 percent
- Biotoxicity to fathead minnows and water fleas was reduced by factors of 4 to 20

Because wetland removal processes are primarily microbial, the technology can be developed with traditional process engineering approaches. Laboratory studies can indicate whether remediation is possible, while bench-scale experiments can determine the proper loading and reactor design. Using this approach, five laboratory proof-of-principle studies and three bench-scale studies have been performed, and at least four successful demonstration reactors have been built to remove heavy metals from different types of water.

A final project goal was to develop a manual that discusses design and operating criteria for constructing a full-scale wetland to treat acid mine discharges. The "Wetland Designs for Mining Operations" manual is available from the National Technical Information Service.

The demonstration program is currently evaluating the effectiveness of biogeochemical processes at the Burleigh Tunnel mine discharge, near Silver Plume, Colorado. Treatment of Burleigh Tunnel discharge is part of the remedy for the Clear Creek Central City Superfund site. Construction of a pilot treatment system began in summer 1993 and was completed in October 1993.

The pilot treatment system is approximately 4200 square feet and consists of an upflow and downflow cell (see figure on previous page). Each cell treats about 10 gallons per minute of flow. Preliminary results show a removal efficiency of greater than 90 percent for zinc, the primary contaminant in the discharge.

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The SITE Program assesses but does not approve or endorse technologies.

ELECTROKINETICS INC.
(Electro-Klean™ Electrokinetic Soil Processing)

TECHNOLOGY DESCRIPTION:

The Electro-Klean™ electrokinetic soil process separates and extracts heavy metals and organic contaminants from soils. Electro-Klean™ can be applied in situ or ex situ, and uses direct currents with electrodes placed on each side of the contaminated soil mass. Conditioning fluids such as suitable acids may be used for electrode (cathode) depolarization to enhance the process.

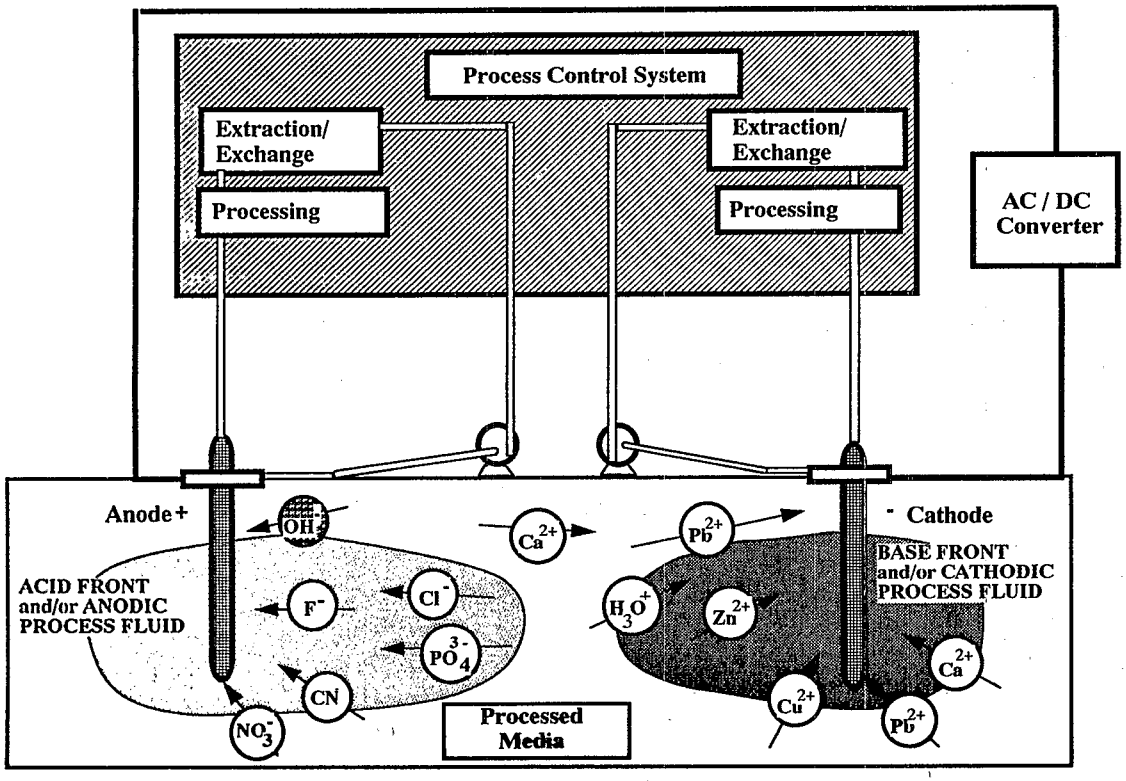
The figure below illustrates the field processing scheme and the flow of ions to respective bore boles (or trenches). Conditioning pore fluids may be added or circulated at the electrodes to control process electrochemistry. Contaminants are electroplated on the electrodes or separated in a posttreatment unit.

An acid front migrates towards the negative electrode (cathode) and contaminants are extracted through electrosmosis (EO) and electromigration (EM). The concurrent mobility of the ions and pore fluid decontaminates the soil mass. The EO and EM supplement or replace conventional pump-and-treat technologies.

Bench-scale results show that the process works in both unsaturated and saturated soils. Pore fluid flow moves from the positive electrodes (anodes) to the cathodes under the effect of the EO and EM forces. Electrode selection is important, since many metal or carbon anodes will rapidly dissolve from attack of strong oxidants.

WASTE APPLICABILITY:

Electro-Klean™ extracts heavy metals, radionuclides, and other inorganic contaminants below their solubility limits. Bench-scale tests have removed arsenic, benzene, cadmium,



Electrokinetic Remediation Process

The SITE Program assesses but does not approve or endorse technologies.

chromium, copper, ethylbenzene, lead, nickel, phenol, trichloroethene, toluene, xylene, and zinc from soils. Bench-scale studies under the SITE Program demonstrated the feasibility of removing uranium and thorium from kaolinite.

Limited pilot-scale field tests resulted in zinc and arsenic removal from clays and saturated and unsaturated sandy clay deposits. Lead and copper were also removed from dredged sediments. Treatment efficiency depended on the specific chemicals, their concentrations, and the buffering capacity of the soil. The technique proved 85 to 95 percent efficient when removing phenol at concentrations of 500 parts per million. In addition, the removal efficiency for lead, chromium, cadmium, and uranium at levels up to 2,000 micrograms per gram (μg/g), ranged between 75 and 95 percent.

STATUS:

Bench-scale laboratory studies investigating heavy metal, radionuclide, and organic contaminant removal are complete, and radionuclide removal studies are complete under the SITE Emerging Technology Program. A pilot-scale laboratory study investigating removal of 2,000 μg/g lead loaded onto kaolinite was completed in May 1993. Removal efficiencies of 90 to 95 percent were obtained. The electrodes were placed 3 feet apart in a 2-ton kaolinite specimen for 4 months, at an energy cost of about $15 per ton. The results of a second pilot-scale laboratory study using 5000 μg/g of lead adsorbed on kaolinite showed similar efficiency results as the earlier study. Bench-scale treatability studies and process enhancement schemes using conditioning fluids continue. Ongoing pilot-scale studies and a field demonstration of removing lead from a military firing range will be conducted during 1994 and 1995; a new electrical separation process of extractive electrolysis will be pilot-tested for removal of multiple heavy metals.

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The SITE Program assesses but does not approve or endorse technologies.

ELECTRON BEAM RESEARCH FACILITY, FLORIDA INTERNATIONAL UNIVERSITY, and UNIVERSITY OF MIAMI
(High-Energy Electron Irradiation)

TECHNOLOGY DESCRIPTION:

High-energy electron irradiation of water solutions and sludges produces a large number of very reactive chemical species, including the aqueous electron (e^-_{aq}), the hydrogen radical ($H^{\cdot}$), and the hydroxyl radical ($OH^{\cdot}$). These short-lived intermediates react with organic contaminants, transforming them to nontoxic by-products.

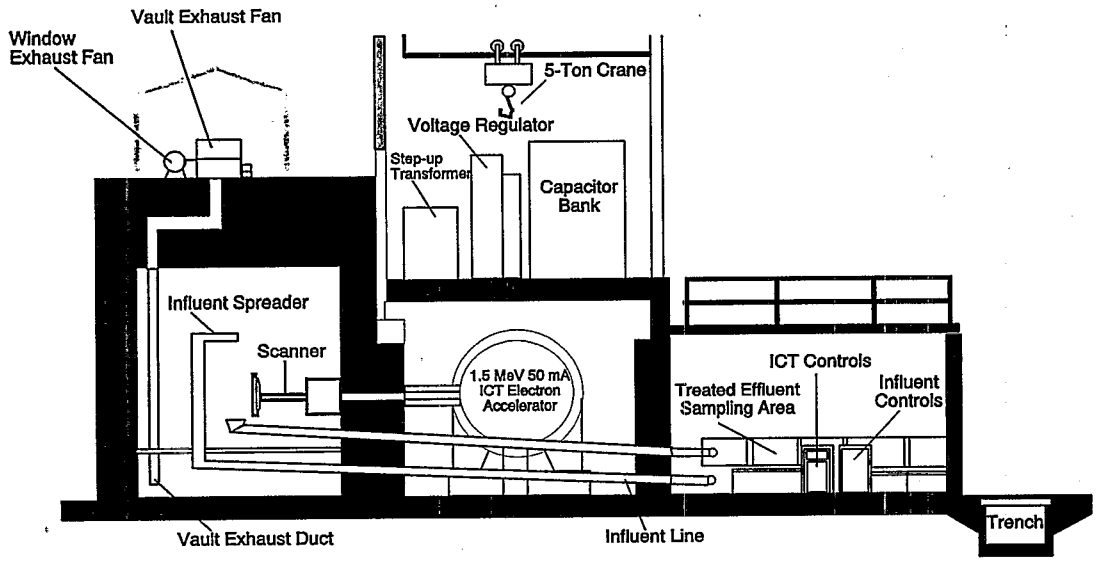
In the principal reaction, the e^-_{aq} ion transfers to halogen-containing compounds, breaking the halogen-carbon bond and liberating halogen anions, such as chloride (Cl^-) or bromide (Br^-). The hydroxyl radical can undergo addition or hydrogen abstraction reactions, producing organic free radicals that decompose in the presence of other hydroxyl radicals and water. In most cases, organics are converted to carbon dioxide, water, and salts. Lower molecular weight aldehydes and carboxylic acids form at low concentrations in some cases. These compounds are biodegradable end products.

During the high-energy electron irradiation process, electricity generates high voltage electrons. The electrons are accelerated by the voltage to approximately 95 percent of the speed of light. They are then directed into a thin stream of water or sludge. All reactions are complete in less than 0.1 second. The electron beam and waste flow are adjusted to deliver the necessary dose of electrons. Although this is a form of ionizing radiation, there is no residual radioactivity.

A full-scale facility can treat more than 170,000 gallons per day. This facility is equipped to handle tank trucks carrying up to 6,000 gallons of waste. The figure below is a schematic of the Electron Beam Research Facility in Miami, Florida.

WASTE APPLICABILITY:

This treatment process can effectively treat in excess of 50 common organic compounds. These compounds include the following:



Electron Beam Research Facility

The SITE Program assesses but does not approve or endorse technologies.

- Trihalomethanes (such as chloroform), which are found in chlorinated drinking water
- Chlorinated solvents, including carbon tetrachloride, trichloroethane, tetrachloroethene (PCE), trichloroethene (TCE), ethylene dibromide, dibromochloropropane, hexachlorobutadiene, and hexachloroethane
- Aromatics found in gasoline, including benzene, toluene, ethylbenzene, and xylene
- Chlorobenzene and dichlorobenzenes
- Phenol
- Dieldrin, a persistent pesticide
- Pentachlorophenol
- Polychlorinated biphenyls
- A variety of other organic compounds

The treatment process is appropriate for removing various hazardous organic compounds from aqueous waste streams and sludges containing up to 8 percent solids.

STATUS:

The high-energy electron irradiation process was accepted into the SITE Emerging Technology Program in June 1990. Studies have now been completed for six organic compounds: TCE, PCE, chloroform, benzene, toluene, and phenol. Removal efficiencies have been determined at three solute concentrations and three pHs (representing varying carbonate/bicarbonate concentrations), and in the presence and absence of 3 percent clay. Reaction by-products have been determined for all six compounds. Trace quantities of formaldehyde and other low molecular weight aldehydes have been detected. Formic acid has also been detected at low concentrations. However, none of these compounds are toxic at these concentrations. Final reports titled "Removal of Phenol from Aqueous Solutions Using High Energy Electron Beam Irradiation" (EPA/540/F-93/509), "Electron Beam Treatment for Trichlorethylene and Tetrachloroethyle from Aqueous Streams" (EPA/540/F-92/009), and "Electron Beam Treatment for Removal of Benzene and Toluene from Aqueous Streams and Sludges" (EPA/540/F-93/502) are available from EPA.

Additional studies are underway to determine destruction efficiencies and to characterize reaction by-products of carbon tetrachloride and methylene chloride.

Based on results from the Emerging Technology Program, this technology has been invited to participate in the SITE Demonstration Program under the company name of High Voltage Environmental Applications, Inc.

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The SITE Program assesses but does not approve or endorse technologies.

ELECTRO-PURE SYSTEMS, INC.
(Alternating Current Electrocoagulation Technology)

TECHNOLOGY DESCRIPTION:

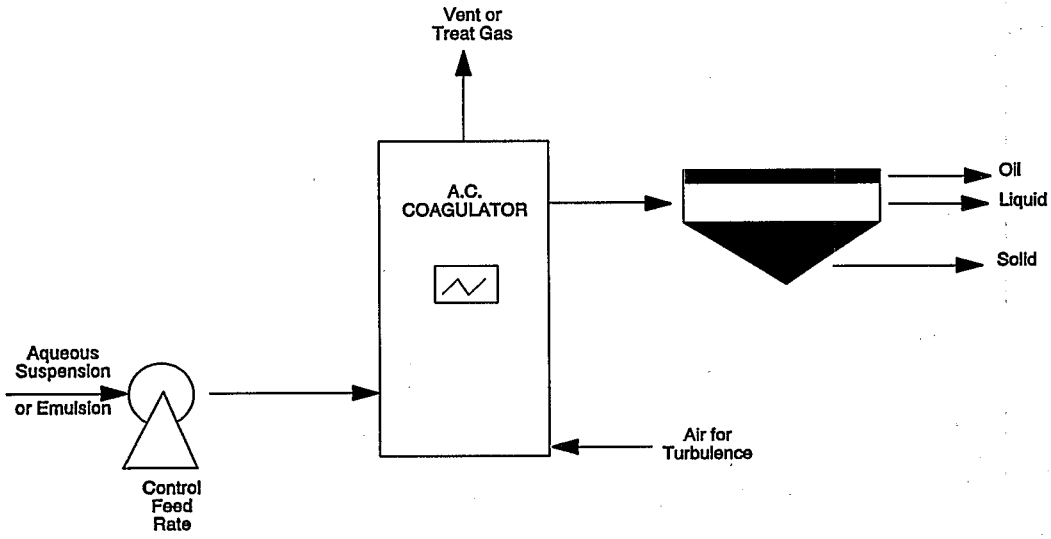
The alternating current electrocoagulation (ACE) technology offers an alternative to metal salts or polymer and polyelectrolyte addition for breaking stable emulsions and suspensions. The technology also removes certain metals and other soluble pollutants in the polishing step of effluent treatment.

Electrocoagulation introduces highly charged polyhydroxide aluminum species that prompt flocculation of colloidal particles and destabilize oil-in-water emulsions. The resulting sludges, achieving liquid-liquid and solid-liquid phase separations, can be filtered and dewatered more readily than those formed by adding chemical flocculents. ACE can break stable aqueous suspensions containing submicron-sized particles of up to 10 percent total solids, and stable aqueous emulsions containing up to 5 percent oil.

The figure below depicts the basic ACE technology process. Electrocoagulation occurs in either a batch or continuous (one-pass) mode in an ACE Separator™ apparatus of one of two designs: 1) cylindrical chambers containing fluidized beds of aluminum alloy pellets entrained between a series of noble metal electrodes, or 2) an upright box containing aluminum plate electrodes spaced at 0.5- to 2-inch intervals. The working volume of the parallel plate unit is 70 liters, and that of the fluidized bed cell, excluding the external plumbing, is 1.5 liters. Neither apparatus has moving parts, and each can be easily integrated into a process treatment train for effluent, pretreatment, or polishing.

Coagulation and flocculation occur simultaneously within the ACE Separator™ as the effluent is exposed to the electric field and aluminum dissolves from the electrodes. This activity usually occurs within 30 seconds for most aqueous suspensions. After charges are neutralized and coagulation begins, the gravity flow transfers the suspension and emulsion to the product separation step.

Product separation occurs in conventional gravity-separation, decant vessels, or through pressure or vacuum filtration. Coagulation and flocculation continue until the phases are com-



Alternating Current Electrocoagulation (ACE)

The SITE Program assesses but does not approve or endorse technologies.

pletely separated. Each oil, water, and solid phase is removed for reuse, recycling, further treatment, or disposal. Waste is removed by surface skimming, bottom scraping, and decanting.

The ACE technology can be used with conventional water treatment systems, including those relying on metal precipitation, membrane separation technologies, mobile dewatering and incineration units, and soil extraction systems. A typical decontamination application, for example, would produce a water phase that could be discharged directly to a stream or local wastewater treatment plant for further treatment. The solid phase would be shipped off site for disposal, and the dewatering filtrate would be recycled. Any floatable material would be reclaimed, refined, or disposed of. The prototype system can treat 700 gallons of contaminated liquid per minute.

WASTE APPLICABILITY:

The ACE technology treats aqueous-based suspensions and emulsions such as contaminated groundwater, surface runoff, landfill leachate, truck wash, scrubber solutions, treated effluents, and extract solutions. The suspensions include solids such as inorganic and organic pigments, clays, metallic powders, metal ores, and natural colloidal matter. The emulsions include a variety of organic solid and liquid contaminants, including petroleum-based by-products.

The technology reduced aqueous clay, latex, and titanium dioxide suspension loadings over 90 percent. The chemical oxygen demand and total organic carbon contents of diesel fuel-spiked slurries have been reduced by over 80 percent. The technology has also removed up to 56 percent lead, 96 percent copper, 91 percent zinc, 97 percent phosphate, and 56 percent fluoride.

ACE technology has recovered fine-grained products such as latex, titanium dioxide, and edible oil solids (animal fats and vegetable oils) from industrial process streams that would otherwise have been discharged to the sewer system.

STATUS:

The ACE technology was accepted into the SITE Emerging Technology Program in July 1988. The second year of laboratory-scale testing and development is complete. The Bulletin (EPA/540/F-92/011) and Emerging Technology Summary (EPA/540/S-93/504) have been submitted to EPA. The research results are described in the *Journal of Air and Waste Management*, Vol. 43, May 1993, pp. 784-789, "Alternating Current Electrocoagulation for Superfund Site Remediation."

Experiments on end-member metals and complex synthetic soil slurries have defined major operating parameters for broad classes of effluents. The technology has been modified to both minimize electric power consumption and maximize effluent throughput rates. Results indicate that electrocoagulation produces aqueous and solid separations comparable to those produced by chemical flocculent addition, but with reduced filtration times and sludge volumes.

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The SITE Program assesses but does not approve or endorse technologies.

ENERGY AND ENVIRONMENTAL ENGINEERING, INC.
(PhotoCAT™ Process)

TECHNOLOGY DESCRIPTION:

The PhotoCAT™ Process technology photochemically oxidizes organic compounds in wastewater using a chemical oxidant, ultraviolet (UV) radiation, and a photocatalyst. The photochemical reaction reduces saturated concentrations of organics in water to nondetectable levels. The energy is predominantly absorbed by the organic compound and the oxidant, making both species reactive. The process can be used as a final treatment step to reduce organic contamination in industrial wastewater and groundwater to acceptable discharge limits.

The existing bench-scale system treats solutions containing up to several hundred parts per million (ppm) of total organic carbon at a rate of 3 gallons per minute. The bench-scale system consists of a photochemical reactor, where oxidation occurs, and associated tanks, pumps, and controls. The UV lamps are high intensity lamps that penetrate the wastewater more effectively. The portable, skid-mounted system's design depends on the chemical composition of the wastewater or groundwater being treated.

Typically, the contaminated wastewater is pumped through a filter unit to remove suspended particles. Next, the filtrate is mixed with stoichiometric quantities of hydrogen peroxide. Finally, this mixture is fed to the photochemical reactor and irradiated. The overall reaction is as follows:

$$C_aH_bX + [2a + 0.5(b - 1)]H_2O_2 \xrightarrow{h\nu} aCO_2 + [2a + (b - 1)]H_2O + HX$$

where C_aH_bX represents a halogenated contaminant in the aqueous phase. Reaction products are carbon dioxide, water, and the appropriate halogen acid.

Reaction kinetics depend on 1) contaminant concentration, 2) peroxide concentration, 3) irradiation dose, and 4) radiation spectral frequency.

WASTE APPLICABILITY:

The PhotoCAT™ process treats industrial wastewater and groundwater containing organics at concentrations up to several hundred parts per million (ppm). Destruction efficiencies greater than two orders of magnitude have been obtained for chlorobenzene, chlorophenol, and phenol, with low to moderate dose rates and initial concentrations of 200 ppm. Destruction efficiencies of three orders of magnitude have been demonstrated on simulated industrial waste streams representative of textile dying operations, with higher dose rates and an initial concentration of 200 ppm. Representative results from recent trials using the UV lamp system are summarized in the table on the previous page. Results from the dye decontamination runs are shown in the figure below.

Contaminant Species	Molecular Weight	Feed Conc (ppm)[1]	Equivalence Ratio	Residence Time (seconds)	Product Cone C/C_0
Chlorobenzene	112	50	3.3	3.7	0.04
Benzene/Toluene	78/93	100/100	3.5	3.8	0.4/0.4
Yellow 106	1374	110	4.2	7.7	0.08
Yellow 49	438	110	1.0	23.0	0.007
Blue 41	463	115	0.6	11.5	0.001
Red 83	1025	140	1.0	7.7	0.008

[1] parts per million by weight

Representative Results from Recent Trials Using the UV Lamp System

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

The PhotoCAT™ process was accepted into the SITE Emerging Technology Program and has been invited to participate in the SITE Demonstration Program. A Final Report (EPA/540/SR-92/080), a Bulletin (EPA/540/F-92/004), and a Summary (EPA/540/SR-92/080) are available from the EPA. Subsequent work, based upon an ultraviolet lamp source for ultraviolet energy, is currently underway under EPA Small Business Industry Research Phase II funding.

Energy and Environmental Engineering, Inc., has made significant improvements on the technology from that presented in the earlier EPA report. These improvements include the following:

- Using the ultraviolet lamp as the energy source
- Improving the photochemical reactor design
- Improving the lamp's design, including lamp intensity and spectral characteristics
- Fixing the catalyst

This improved technology is called the PhotoCAT™ process. A cost competitive system that completes mineralization can be designed and built to treat industrial strength wastewater at 10 to 1000 ppm contaminant concentration levels.

Energy and Environmental Engineering, Inc., has formed a new company, *UV technologies, inc.*, to commercialize the technology. Energy and Environmental Engineering, Inc., will conduct treatability studies for prospective clients, and is seeking funding to commercialize the venture.

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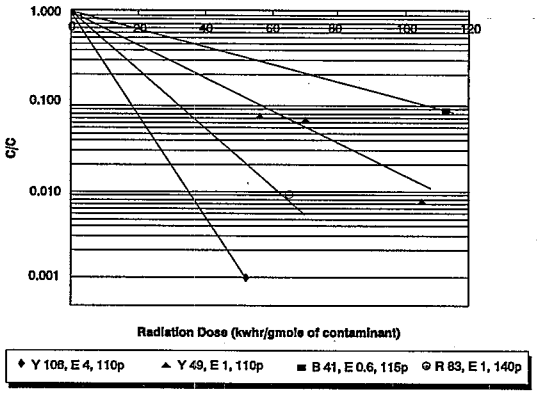

Experimental Results - Simulated Dye Solutions

The SITE Program assesses but does not approve or endorse technologies.

ENERGY AND ENVIRONMENTAL RESEARCH CORPORATION
(Hybrid Fluidized Bed System)

TECHNOLOGY DESCRIPTION:

The Hybrid Fluidized Bed (HFB) system treats contaminated solids and sludges by incinerating organic compounds and extracting and detoxifying volatile metals. The system consists of three stages: a spouted bed, a fluidized afterburner, and a high-temperature particulate soil extraction system.

First, the spouted bed rapidly heats solids and sludges to allow extraction of volatile organic and inorganic compounds. The spouted bed retains larger soil clumps until they are reduced in size, but allows fine material to quickly pass through. This segregation process is beneficial because organic contaminants in fine particles vaporize rapidly. The decontamination time for large particles is longer due to heat and mass transfer limitations.

The central spouting region is operated with an inlet gas velocity of greater than 150 feet per second. This velocity creates an abrasion and grinding action, rapidly reducing the size of the feed materials through attrition. The spouted bed operates between 1,500 and 1,700 degrees Fahrenheit, under oxidizing conditions.

Organic vapors, volatile metals, and fine soil particles are carried from the spouted bed through an open-hole type distributor, which forms the bottom of the second stage, the fluidized bed afterburner. The afterburner provides sufficient retention time and mixing to incinerate the organic compounds that escape the spouted bed, resulting in a destruction and removal efficiency greater than 99.999 percent. In addition, the afterburner contains bed materials that absorb metal vapors, capture fine particles, and promote formation of insoluble metal silicates. A slightly sticky bed is advantageous because of its particle retention properties.

In the third stage, the high temperature particulate soil extraction system removes clean processed soil from the effluent gas stream with one or two hot cyclones. The clean soil is extracted hot to prevent unreacted volatile metal species from condensing in the soil. Off-gases are then quenched and passed through a conventional baghouse to capture the condensed metal vapors.

Generally, material handling problems create major operational difficulties for soil cleanup devices. The HFB uses a specially designed auger feed system. Solids and sludges are dropped through a lock hopper system into an auger shredder, which is a rugged, low-revolutions per minute feeding-grinding device. Standard augers are simple and reliable, but are susceptible to clogging from feed compression in the auger. In the HFB system, the auger shredder is close-coupled to the spouted bed to reduce compression and clump formation during feeding. The close couple arrangement locates the tip of the auger screw several inches from the internal surface of the spouted bed, preventing soil plugs formation.

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

This technology is applicable to soils and sludges contaminated with organic and volatile inorganic contaminants. Nonvolatile inorganics are not affected.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in January 1990. Design and construction of the commercial prototype HFB and a limited shakedown are completed. An Emerging Technology Bulletin (EPA/540/F-93/508) is available from EPA.

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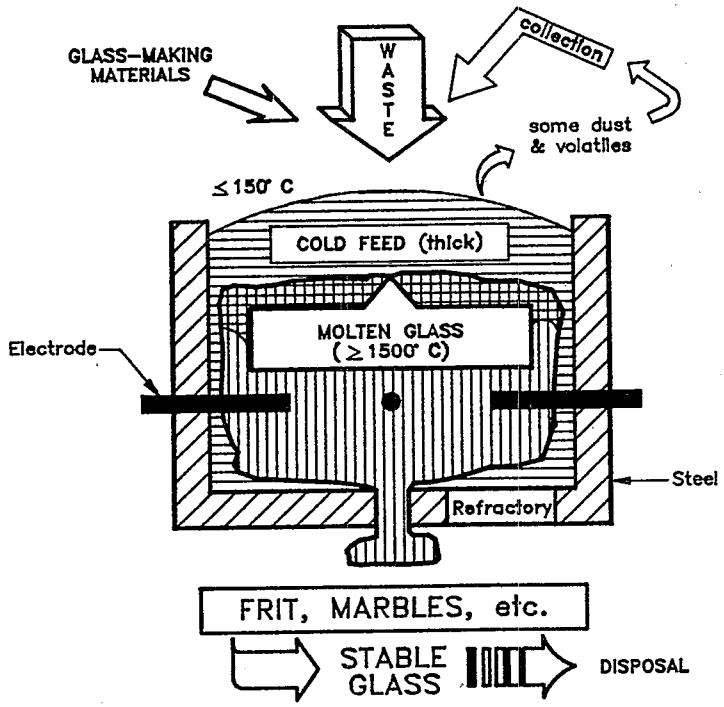
The SITE Program assesses but does not approve or endorse technologies.

FERRO CORPORATION
(Waste Vitrification Through Electric Melting)

TECHNOLOGY DESCRIPTION:

Vitrification technology converts contaminated soils, sediments, and sludges into oxide glasses, chemically rendering them nontoxic and suitable for landfilling as nonhazardous materials. Successful vitrification of soils, sediments, and sludges requires 1) development of glass compositions tailored to a specific waste, and 2) glass melting technology that can convert the waste and additives into a stable glass without producing toxic emissions. Because of its low toxic emission rate, an electric melter may be more beneficial than a fossil fuel melter for vitrifying toxic wastes.

In an electric melter, glass — an ionic conductor of relatively high electrical resistivity — stays molten with joule heating. Such melters process waste under a relatively thick blanket of feed material, which forms a counterflow scrubber that limits volatile emissions (see figure below). In contrast, fossil fuel melters have large, exposed molten glass surface areas from which hazardous constituents can volatilize. Commercial electric melters have significantly reduced the loss of inorganic volatile constituents such as boric anhydride (B_2O_3) or lead oxide (PbO). Because of its low emission rate and small volume of exhaust gases, electric melting is a promising technology for incorporating waste into a stable glass.



Electric Furnace Vitrification

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

Vitrification stabilizes inorganic components found in hazardous waste. In addition, the high temperature involved in glass production (about 1,500 degrees Celsius) decomposes anthracene, bis(2-ethylhexyl phthalate), and pentachlorophenol in the waste. The decomposition products can easily be removed from the low volume of melter off-gas.

STATUS:

Several glass compositions suitable for processing synthetic soil matrix IV (SSM-IV) have been developed and subjected to toxicity characteristic leaching procedure testing (TCLP). Ten independent replicates of the preferred composition produced the following results:

	TCLP analyte concentration, parts per million	
Metal	Remediation Limit	Mean of Glass Replicates
As	5	<0.100
Cd	1	<0.010
Cr	5	0.019
Cu	5	0.355
Pb	5	0.130
Ni	5	<0.010
Zn	5	0.293

The mean analyte concentrations were less than 10 percent of the remediation limit at a statistical confidence of 95 percent.

SSM-IV and additives (sand, soda ash, and other minerals) required to convert SSM-IV to the preferred glass composition have been processed in a laboratory-scale electric melter. Three separate campaigns have produced glass at 17 pounds per hour at a fill of 67 percent SSM-IV and 33 percent glass-making additives. Ferro Corporation's experience indicates that an equivalent rate would be 1 ton per hour in an electric melter used to treat wastes at a Superfund site.

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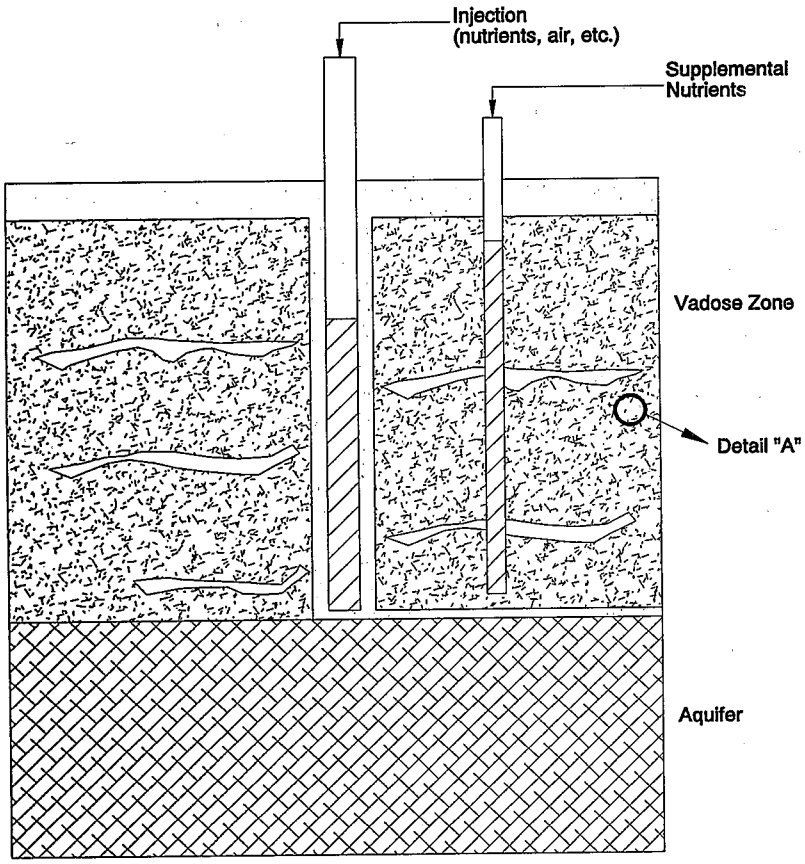
The SITE Program assesses but does not approve or endorse technologies.

HAZARDOUS SUBSTANCE MANAGEMENT RESEARCH CENTER at NEW JERSEY INSTITUTE OF TECHNOLOGY
(Pneumatic Fracturing/Bioremediation)

TECHNOLOGY DESCRIPTION:

This technology integrates two innovative techniques — pneumatic fracturing and bioremediation — to enhance in situ remediation of soils contaminated with petroleum contaminants. For pneumatic fracturing, high pressure air or gas is injected into soil formations at controlled flow rates and pressures. In less permeable soils, pneumatic fracturing creates conductive channels in soil formations. These channels increase soil permeability and exposed surface area, accelerating contaminant treatment and removal. In more permeable soils, pneumatic fracturing provides a means for rapidly aerating the soil formation.

Pneumatic fracturing enhances microbial processes by staggering spatial distribution for maximum effectiveness (see figure below). Aerobic processes dominate at the fracture interfaces and for a limited distance away from the fracture. Oxygen depletion during aerobic biodegradation allows methanogenic and denitrifying populations to form at greater distances from the fractures. Contaminants diffuse toward the fracture, serving as a substrate for various microbial populations. This stacking arrangement enhances growth of aerobic microbial populations by reducing substrate concentrations in the denitrifying and methanogenic zones (see figure on next page).



Vadose Zone Biodegradation With Fracturing and Vapor Stripping

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

This technology remediates soil contaminated with petroleum hydrocarbons, benzene, toluene, and xylene.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1991, and will be demonstrated at Marcus Hook, Pennsylvania. Site characterization is complete; pilot-scale field testing is underway and is scheduled for completion in July 1994.

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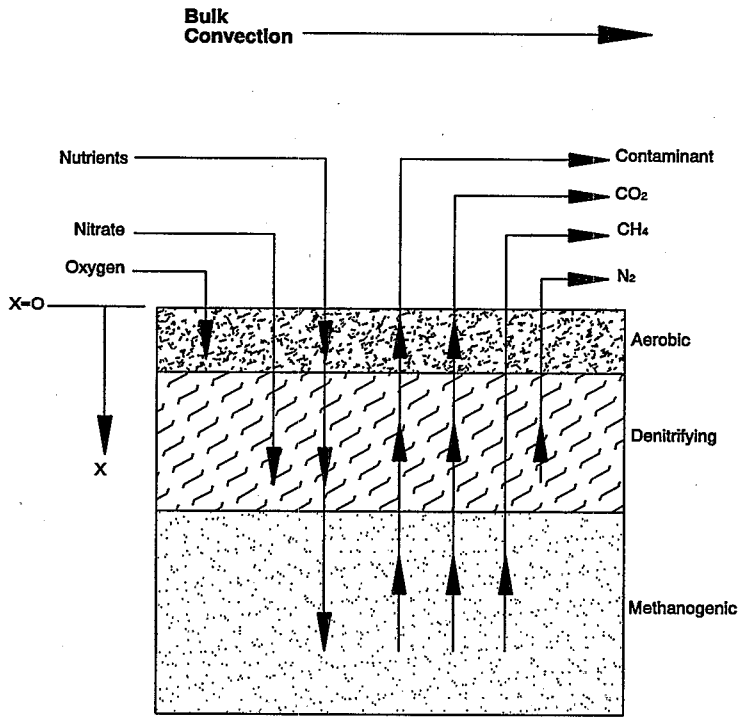


Contaminant, Oxygen, Nutrient, and Reaction Product Fluxes

The SITE Program assesses but does not approve or endorse technologies.

INSTITUTE OF GAS TECHNOLOGY
(Chemical and Biological Treatment)

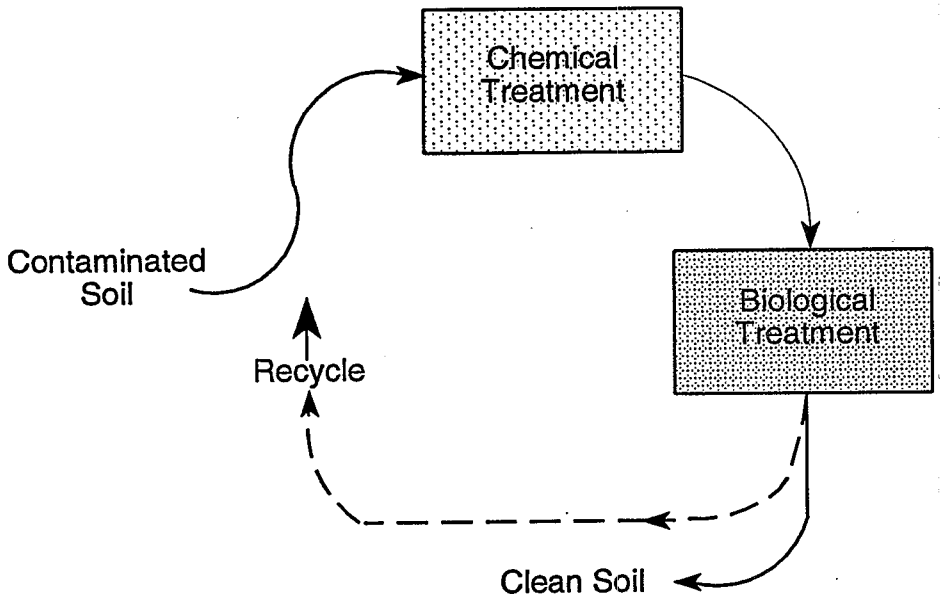
TECHNOLOGY DESCRIPTION:

The Institute of Gas Technology's (IGT) chemical and biological treatment (CBT) process remediates sludges and soils contaminated with organic pollutants, such as polyaromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). The treatment system combines two remedial techniques: 1) chemical oxidation as pretreatment, and 2) biological treatment using aerobic and anaerobic biosystems in sequence or alone, depending on the waste (see figure below). The CBT process uses mild chemical treatment to produce intermediates that are biologically degraded, reducing the cost and risk associated with a more severe treatment process, such as incineration.

The contaminated material is treated with a chemical reagent that degrades the organo-pollutants to carbon dioxide, water, and more biodegradable partially-oxidized intermediates. In the second stage of the CBT process, biological systems degrade the hazardous residual materials and the partially-oxidized material from the first stage. Chemically-treated wastes are subject to cycles of aerobic and anaerobic degradation if aerobic or anaerobic treatment alone is not sufficient. Several cycles of chemical and biological treatment are also used for extremely recalcitrant contaminants.

WASTE APPLICABILITY:

The CBT process can be applied to 1) soils and sludges containing high waste concentrations that would typically inhibit bioremediation, and 2) low waste concentrations when bioremediation alone is too slow. The process is not adversely affected by radionuclides or heavy metals. Depending on the types of heavy metals present, these metals will either bioaccumulate in the biomass, complex with organic or inorganic material in the soil slurries, or solubilize in the recycled water. The CBT process can be applied to a wide range of organic pollutants, including alkenes, chlorinated alkenes, aromatics, substituted aromatics, and complex



Chemical and Biological Treatment (CBT) Process

The SITE Program assesses but does not approve or endorse technologies.

aromatics. Applicable matrices include soil, sludge, groundwater, and surface water.

STATUS:

IGT evaluated the CBT process under the SITE Emerging Technology Program for two years. This evaluation included bench-scale studies of important operational parameters for applying the CBT technology to soils and sludges contaminated with PCBs. Results indicated that this technology can treat various PCB-contaminated matrices with modifications to the original treatment protocol that increases the availability of the PCBs. Results are available in the Emerging Technology Bulletin (EPA/540/F-94/504).

The standard reagent concentration of 2.5 percent H_2O_2 and ferrous sulfate resulted in the greatest degradation in both the lower and high chlorinated compounds. When compared to the control, 40 percent of total PCBs were removed by chemical degradation and as much as 90 percent of some PCB congeners were removed. As the reagent concentration increases, the degradation of PCBs increases; however, the PCBs with less than five chlorine groups are more susceptible than PCBs with greater than five chlorine groups. This pattern complements the anaerobic and aerobic biodegradation of PCBs in that it aggressively attacks the intermediate biphenyl compounds with three to five chlorine groups, anaerobic biodegradation effectively reduces the concentration of higher chlorinated biphenyls (four to eight chlorine groups) by 44 to 70 percent and aerobic biodegradation efficiently removes mono- and di-chlorinated biphenyls. Experiments conducted using actual contaminated soil demonstrated greater than 50 percent removal of all congeners with a single cycle of the integrated chemical/biological degradation.

IGT's CBT technology continues to be successfully applied to PAH-contaminated soils. The CBT process consistently outperforms conventional bioremediation, especially with multi-ring (four to six) PAH compounds. The CBT process increases both the rate and extent of contaminant removal from various types of soils. Two successful field tests, one solid-phase land treatment and one soil slurry treatment, have been conducted under other gas industry-supported programs. The field experiment showed that the integrated treatment system removed about 50 percent more total PAHs and 90 percent more carcinogenic PAHs than those conventionally biotreated. The integrated system's results exceed the treatment goals which had been established and were reached in 42 days. This field study verified the effectiveness of the integrated biological-chemical treatment process on a large-scale demonstration. Also, the field data show that the integrated process results in higher cleanup levels at faster rates compared with biological treatment alone.

IGT was invited to participate in the SITE Demonstration Program based on results from the Emerging Technology Program. IGT is evaluating possible sites for a full-scale demonstration.

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The SITE Program assesses but does not approve or endorse technologies.

INSTITUTE OF GAS TECHNOLOGY
(Fluid Extraction-Biological Degradation Process)

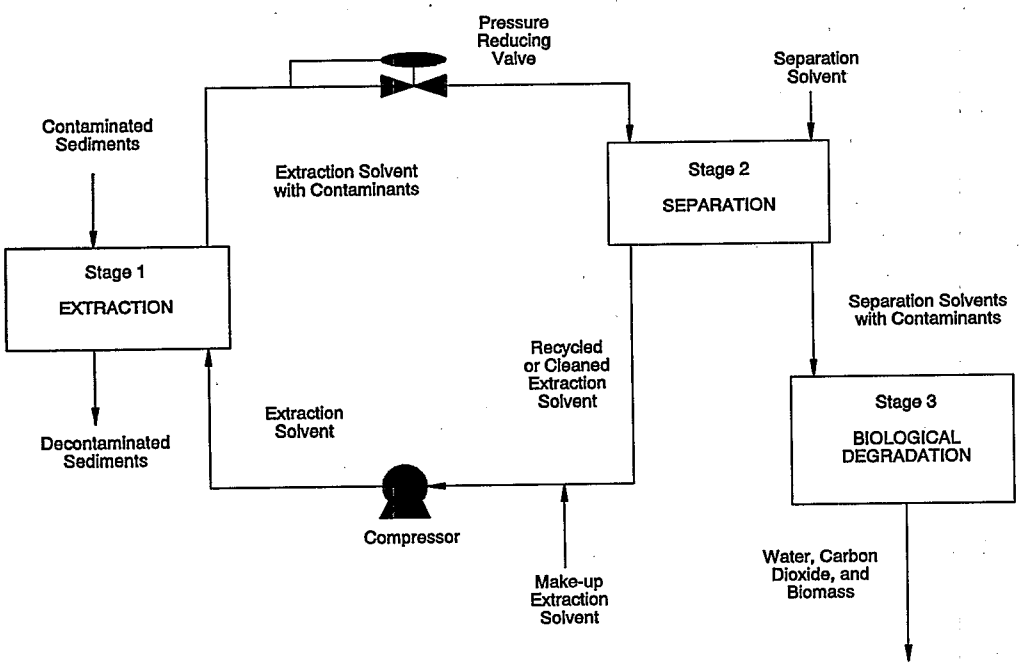
TECHNOLOGY DESCRIPTION:

The fluid extraction-biological degradation (FEBD) process is a three-step process that remediates organic contaminants from soil (see figure below). The process combines three distinct technologies: 1) fluid extraction, which removes the organics from contaminated solids; 2) separation, which transfers the pollutants from the extract to a biologically-compatible solvent or activated carbon carrier; and 3) biological degradation, which destroys the pollutants and leaves innocuous end-products.

In the fluid extraction step, excavated soils are placed in a pressure vessel and extracted with a recirculated stream of supercritical or near-supercritical carbon dioxide. An extraction co-solvent may be added to enhance the removal of additional contaminants.

During separation, organic contaminants are transferred to a biologically-compatible separation solvent such as water or a water-methanol mixture. The separation solvent is then sent to the final stage of the process, where bacteria degrade the waste to carbon dioxide and water. Clean extraction solvent is then recycled for use in the extraction stage.

Organic contaminants are biodegraded in above-ground aerobic bioreactors, using mixtures of bacterial cultures capable of degrading the contaminants. Selection of cultures is based on site characteristics. For example, if a site is contaminated mainly with polynuclear aromatic hydrocarbons (PAH), cultures able to metabolize or co-metabolize these hydrocarbons are used. The bioreactors can be configured to enhance the rate and extent of biodegradation.



Fluid Extraction-Biological Degradation Process

The SITE Program assesses but does not approve or endorse technologies.

Research continues on using bound activated carbon in a carrier system during the separation step. Bound activated carbon should allow high pressure conditions to be maintained in the fluid extraction step, enhancing extraction efficiency and decreasing extraction time. Bound activated carbon should also limit the loss of carbon dioxide, thereby decreasing costs. The activated carbon containing the bound PAHs could then be treated in the biodegradation step by converting the carrier system to a biofilm reactor. These activated carbon carrier systems could then be recycled back into the high pressure system of the extraction and separation steps.

WASTE APPLICABILITY:

This technology removes organic compounds from contaminated solids. It is more effective on some classes of organics, such as hydrocarbons (for example, gasoline and fuel oils), than on others, such as halogenated solvents and polychlorinated biphenyls. The process has also been effective in treating nonhalogenated aliphatic hydrocarbons and PAHs.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in June 1990. The Institute of Gas Technology has evaluated all three stages of the technology with soils from a Superfund site and from three town gas sites. These soils exhibited a variety of physical and chemical characteristics. Approximately 85 to 99 percent of detectable PAHs, including two- to six-ring compounds, were removed from the soils.

The measurable PAHs were biologically converted in both batch-fed and continuously-fed, constantly stirred tank reactors. The conversion rate and removal efficiency were high in all systems. The PAHs were biologically removed or transformed at short hydraulic retention times. All PAHs, including four- to six-ring compounds, were susceptible to biological removal.

Results from this project were published in an Emerging Bulletin (EPA/540/F-94/501), which is available from EPA. An article was submitted to the *Journal of Air and Waste Management*.

Potential users of this technology have expressed interest in continuing research. This technology will be considered for the SITE Demonstration Program for application to town gas sites, wood treatment sites, and other contaminated soils and sediments.

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The SITE Program assesses but does not approve or endorse technologies.

IT CORPORATION
(Batch Steam Distillation and Metal Extraction)

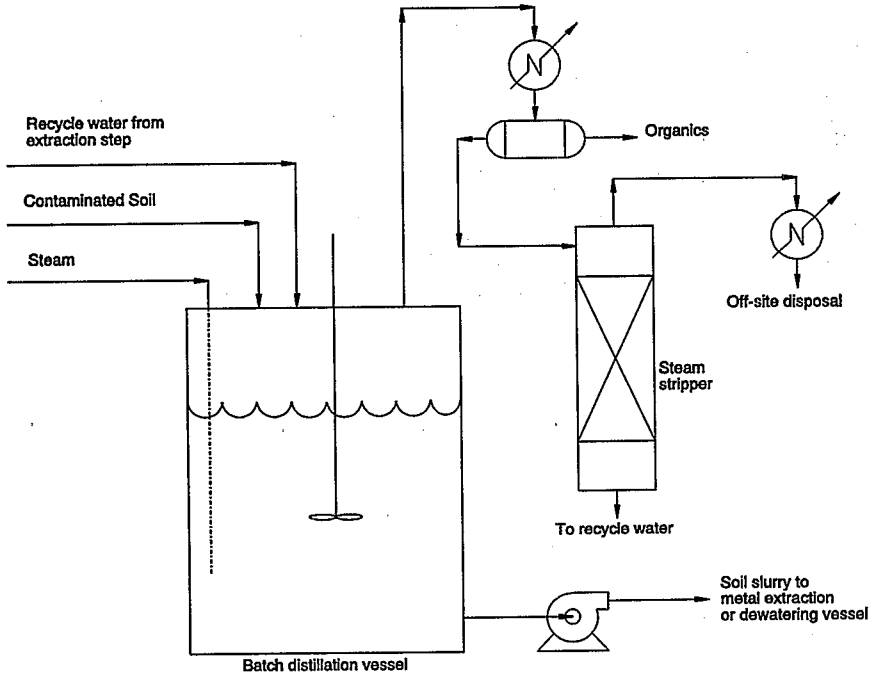
TECHNOLOGY DESCRIPTION:

The batch steam distillation and metal extraction treatment process is a two-stage system that treats soils contaminated with organics and inorganics. This system uses conventional, readily available process equipment, and does not produce hazardous combustion products. Hazardous materials are separated from soils as concentrates, which can then be disposed of or recycled. The treated soil can be returned to the site.

During treatment, waste soil is slurried in water and heated to 100 degrees Celsius. This heat vaporizes volatile organic compounds (VOC) and produces an amount of steam equal to 5 to 10 percent of the slurry volume. Resulting vapors are condensed and decanted to separate organic contaminants from the aqueous phase. Condensed water from this step can be recycled through the system after further treatment to remove soluble organics. The soil is then transferred as a slurry to the metals extraction step.

In the metals extraction step, the soil slurry is washed with hydrochloric acid. Subsequent countercurrent batch washing with water removes residual acid from the soil. The solids are then separated from the final wash solution by gravimetric sedimentation. Most heavy metals are converted to chloride salts in this step. The acid extract stream is then routed to a batch distillation system, where excess hydrochloric acid is recovered (see figure below). Bottoms from the still, which contain heavy metals, are precipitated as hydroxide salts and drawn off as a sludge for off-site disposal or recovery.

As a batch process, this treatment technology is targeted at sites with less than 5,000 tons of soil requiring treatment. Processing time depends on equipment size and batch cycle times; roughly



Batch Steam Distillation Step

The SITE Program assesses but does not approve or endorse technologies.

one batch of soil can be treated every four hours. Estimated treatment costs per ton, including capital recovery, for the two treatment steps are as follows:

Batch Steam Distillation	
500-ton site	$299-393/ton
2,500-ton site	$266-350/ton
Metals Extraction (including acid recovery)	
500-ton site	$447-619/ton
2,500-ton site	$396-545/ton

WASTE APPLICABILITY:

This process may be applied to soils and sludges contaminated with organics, inorganics, and heavy metals.

STATUS:

The batch steam distillation and metal extraction process was accepted into the SITE Emerging Technology Program in January 1988. Under the program, three pilot-scale tests have been completed on three soils, for a total of nine tests. The removal rates for benzene, toluene, ethylbenzene, and xylene were greater than 99 percent. The removal rates for chlorinated solvents ranged from 97 percent to 99 percent. One acid extraction and two water washes resulted in a 95 percent removal rate for heavy metals. Toxicity characteristic leaching procedure tests on the treated soils showed that soils from eight of the nine tests met leachate criteria. Data were also collected on the recovery rate for excess acid and the removal rate for precipitation of heavy metals into a concentrate.

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The SITE Program assesses but does not approve or endorse technologies.

IT CORPORATION
(Photolytic and Biological Soil Detoxification)

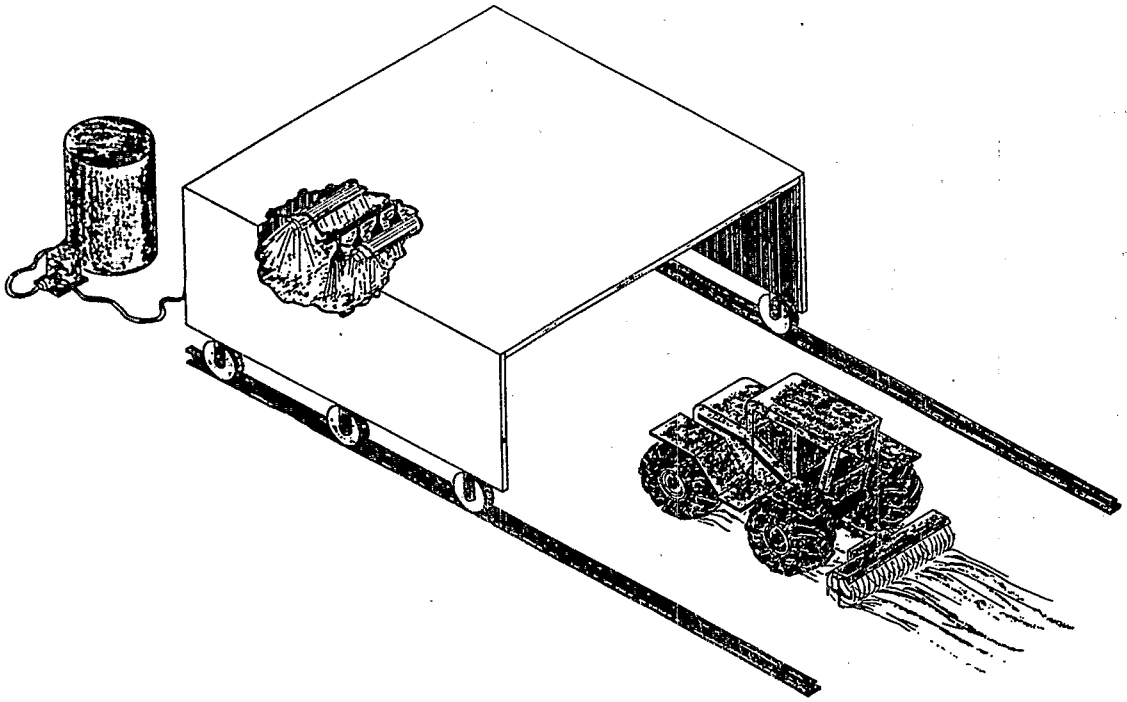
TECHNOLOGY DESCRIPTION:

This technology is a two-stage, in situ photolytic and biological detoxification process for shallow soil contamination. The first step in the process degrades the organic contaminants with ultraviolet (UV) radiation. The photolytic degradation rate is several times faster with artificial UV light than with natural sunlight. The degradation process is enhanced by adding detergent-like chemicals (surfactants) to mobilize the contaminants. Photolysis of the contaminants converts them to more easily degraded compounds. Periodic sampling and analysis determines when photolysis is complete. Biodegradation, the second step, further destroys organic contaminants and detoxifies the soil.

When sunlight is used to treat shallow soil contamination, the soil is first tilled with a power tiller and sprayed with surfactant. The soil is tilled frequently to expose new surfaces and often sprayed. Water may also be added to maintain soil moisture.

When UV lights are used, parabolic reflectors suspended over the soil increase the amount of UV irradiation (see figure below). After photolysis is complete, biodegradation is enhanced by adding microorganisms and nutrients and further tilling the soil.

When these techniques are applied to soils with deep contamination, excavated soil is treated in a specially constructed shallow treatment basin



Photolytic Degradation Process Using UV Lights

The SITE Program assesses but does not approve or endorse technologies.

that meets Resource Conservation and Recovery Act requirements. When soil contamination is shallow, photolysis and housing prevent contaminants from moving down to groundwater.

The only treatment residuals are soil contaminated with surfactants and the end metabolites of the biodegradation processes. The end metabolites depend on the original contaminants. The surfactants are common materials used in agricultural formulations.

WASTE APPLICABILITY:

This photolytic and biological soil detoxification process destroys organics, particularly dioxins such as tetrachlorodibenzo-p-dioxin (TCDD), polychlorinated biphenyls (PCB), other polychlorinated aromatics, and polynuclear aromatic hydrocarbons.

STATUS:

Bench-scale tests conducted on about 5,000 cubic yards of PCB- or dioxin-contaminated soil showed that the effectiveness of surface irradiation to destroy TCDDs or PCBs is strongly influenced by soil type. Early tests on sandy soils showed greater than 90 percent removals for both TCDDs and PCBs. However, a high humic content decreased the effectiveness of the UV photolysis. Soil contaminated with PCBs in the bench-scale tests had a high clay content. The highest removal rate for these soils was 30 percent, measured over a 16-hour irradiation time.

The bench-scale tests used a medium-pressure mercury UV lamp; sunlight was ineffective. No significant improvement in PCB destruction was achieved using a pulsed UV lamp.

The process was also tested with Fenton's Reagent chemistry as an alternate method of degrading PCBs to more easily biodegraded compounds. PCB destruction ranged from nondetectable to 35 percent. Preliminary data indicate that no significant change in PCB chlorine level distribution occurred during treatment.

Other studies examined PCB biodegradability in 1) soil treated with a surfactant and UV radiation, 2) untreated soil, and 3) soil known to have PCB-degrading organisms. Study results were as follows:

- PCB removal in the UV-treated soil, untreated soil, and soil with known biological activity was higher when augmented with an isolated PCB degrader (microorganism).
- In the untreated soil, biphenyl was more efficient at inducing PCB degradation than 4-bromobiphenyl.
- For the treated soil, surfactant treatment may have inhibited microbial activity due to high total organic carbon and low pH.

Isolation and enrichment techniques have made it possible to isolate microorganisms capable of biodegrading PCBs in contaminated soil.

A bulletin (EPA/540/F-94/502), containing results from the study, is available from EPA.

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The SITE Program assesses but does not approve or endorse technologies.

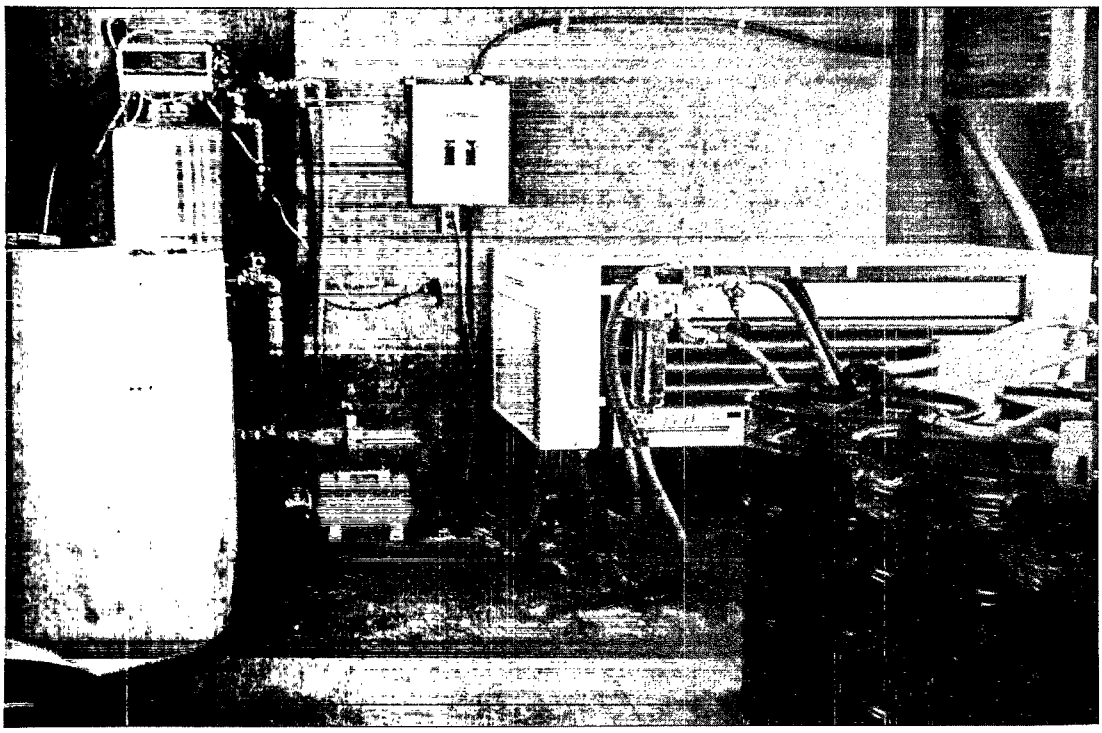
MATRIX PHOTOCATALYTIC INC.
(formerly NUTECH ENVIRONMENTAL)
(Photocatalytic Water Treatment)

TECHNOLOGY DESCRIPTION:

The Matrix Photocatalytic Inc. (Matrix), formerly Nutech Environmental, photocatalytic oxidation system, shown in the photograph below, efficiently removes and destroys dissolved organic contaminants from water in a continuous flow process at ambient temperatures. When excited by light, the titanium dioxide (TiO_2) semiconductor catalyst generates hydroxyl radicals that oxidatively break the carbon bonds of hazardous organic compounds. The catalyst also generates electron holes, which are powerful reducing species.

The Matrix system, when given sufficient time, converts organics such as polychlorinated biphenyls (PCB); phenols; benzene, toluene, ethylbenzene, and xylene (BTEX); and others to carbon dioxide and water. Typically, efficient destruction occurs between 30 seconds and 2 minutes actual exposure time. Total organic carbon removal takes longer, depending on the other organic molecules and their molecular weights.

The Matrix system was initially designed to destroy organic pollutants or to remove total organic carbon in drinking water, groundwater, and plant process water. The Matrix system also destroys organic pollutants such as PCBs, polychlorinated dibenzodioxins, polychlorinated dibenzofurans, chlorinated alkenes, chlorinated phenols, chlorinated benzenes, alcohols, ketones,



10-gallon-per-minute TiO_2 Photocatalytic System Treating BTEX in Water

The SITE Program assesses but does not approve or endorse technologies.

aldehydes, and amines. Inorganic pollutants such as cyanide, sulphite, and nitrite ions can be oxidized to cyanate ion, sulphate ion, and nitrate ion, respectively.

WASTE APPLICABILITY:

The Matrix system can treat a wide range of concentrations of organic pollutants in industrial wastewater, and can be applied to the ultrapure water industry and the drinking water industry. The Matrix system can also remediate groundwater.

STATUS:

The Matrix system was accepted into the SITE Emerging Technology Program in May 1991. Technological advances since that time include the following:

- The Matrix system has treated effluents with contaminants, such as solvents and alcohols, as high as 30,000 parts per million (ppm), and has achieved effluent qualities as low as 5 parts per trillion.
- Performance has quadrupled over 1992 standards.
- Numerous extended field trials have been conducted on raw effluent contaminated with a variety of organics, mainly BTEX, trichloroethene, and methyl tertiary butyl ether. Average treatment time was 60 seconds at a direct operating cost of $1 to $2 per 1,000 gallons.
- The technology was used for 6 months in a sustained field operation on groundwater contaminated with 1 ppm ferrous ion (Fe^{+2}) with no appreciable iron fouling.
- Modular systems have been developed for high flow rates with capacity increments of 5 gallons per minute. Capital costs are highly competitive with ultraviolet/hydrogen peroxide technologies while operating costs are usually one-fifth to one-third less.
- Matrix has successfully designed and field tested support systems for unattended operation.
- The Matrix system has successfully treated highly turbid effluents and dyes in plant operations.

The research was completed in September 1993. Two peer-reviewed journal articles are available through National Technical Information Services (NTIS), document Nos. PB93-222883 and PB93-130184. For a comprehensive bibliography of TiO_2 research, please obtain NTIS document No. DE94-006906.

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The SITE Program assesses but does not approve or endorse technologies.

MEMBRANE TECHNOLOGY AND RESEARCH, INC.
(VaporSep™ Membrane Process)

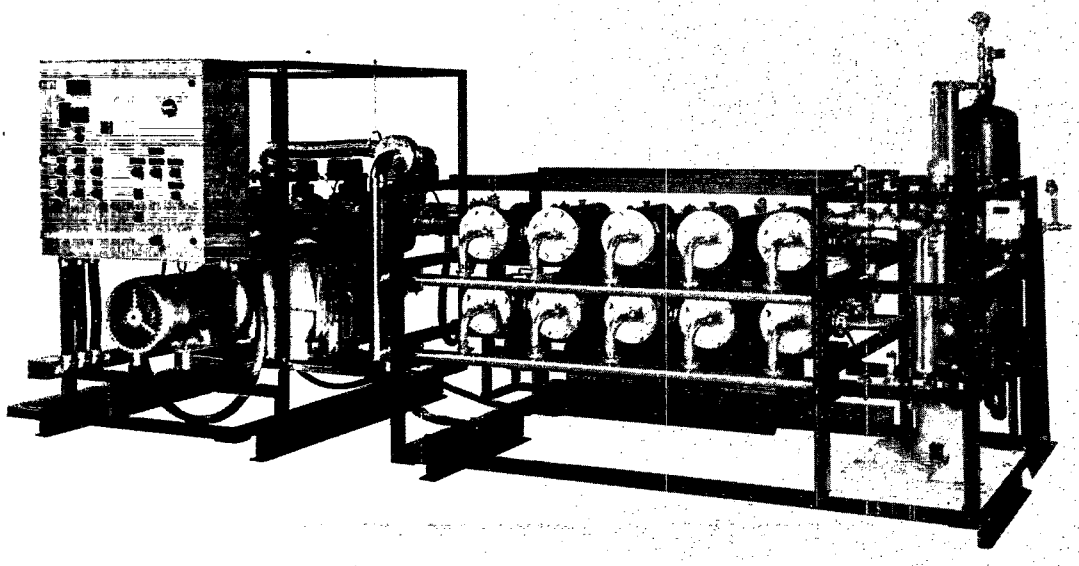
TECHNOLOGY DESCRIPTION:

Membrane Technology and Research, Inc.'s, VaporSep™ system uses synthetic polymer membranes to remove organic vapors from contaminated air streams (see photograph below). The process generates a clean air stream and a liquid organic stream for reuse or disposal.

Air laden with organic vapor contacts one side of a membrane that is 10 to 100 times more permeable to the organic compound than to air. The membrane separates the gas into two streams: a permeate stream containing most of the organic vapor, and a clean residual air stream. The organic vapor is condensed and removed as a liquid; the purified air stream may be vented or recycled.

The VaporSep™ system maintains a lower vapor pressure on the permeate side of the membrane to drive the permeation process. This pressure difference can be created by either compressing the feed stream or using a vacuum pump on the permeate stream.

Over 40 VaporSep™ systems have been built or are under construction. These systems range in capacity from 1 to 100 standard cubic feet per minute. VaporSep™ systems are significantly smaller than carbon adsorption systems of similar capacity, and can be configured to treat a wide range of feed flow rates and compositions. The VaporSep™ system has been tested on air streams contaminated with a wide range of organic compounds at concentrations of 100 to over 100,000 parts per million.



A VaporSep™ Membrane Organic Vapor Recovery System

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

VaporSep™ systems can treat most air streams containing flammable or nonflammable halogenated and nonhalogenated organic compounds, including chlorinated hydrocarbons, chlorofluorocarbons (CFC), and fuel hydrocarbons. Typical applications include the following:

- Reduction of process vent emissions, such as those regulated by EPA's source performance standards for the synthetic organic chemical manufacturing industry
- Treatment of air stripper exhaust before discharge to the atmosphere
- Recovery of CFCs and hydrochlorofluorocarbons

The VaporSep™ system removes between 90 and 99 percent of the organic vapor, depending on the class of organic compound and the system design. The system does not produce any secondary wastes, and only produces a small volume of organic condensate. The concentration of organics in the purified air stream is generally low enough for discharge to the atmosphere.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in January 1990. The process, demonstrated at both the bench- and pilot-scales, achieved removal efficiencies of over 99.5 percent for selected organic compounds.

Over twenty VaporSep™ systems have been successfully installed for the following industrial processes:

- CFC and halocarbon recovery from process vents and transfer operations
- CFC recovery from refrigeration systems
- Vinyl chloride monomer recovery from polyvinyl chloride manufacturing operations
- CFC-12/ethylene oxide recovery from sterilizer emissions

The VaporSep™ system successfully treated an air stream from a soil vacuum extraction operation at a U.S. Department of Energy site.

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The SITE Program assesses but does not approve or endorse technologies.

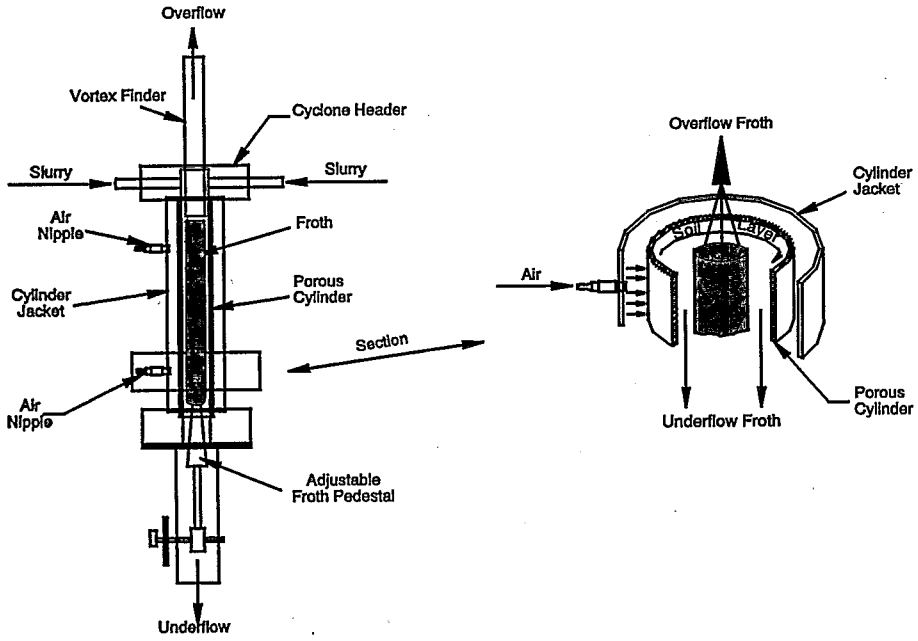
MONTANA COLLEGE OF MINERAL SCIENCE & TECHNOLOGY
(Air-Sparged Hydrocyclone)

TECHNOLOGY DESCRIPTION:

The air-sparged hydrocyclone (ASH) was developed at the University of Utah during the early 1980s to achieve fast flotation of fine particles in a centrifugal field. The ASH consists of two concentric right-vertical tubes with a conventional cyclone header at the top and a froth pedestal at the bottom (see figure below). The inner tube is a porous tube through which air is sparged. The outer tube serves as an air jacket to evenly distribute air through the porous inner tube.

Slurry is fed tangentially through the conventional cyclone header to develop a swirl flow of a certain thickness in the radial direction (the swirl-layer thickness). The swirl is discharged through an annular opening between the porous tube wall and the froth pedestal. Air is sparged through the porous inner tube wall and is sheared into small bubbles. These bubbles are then radially transported, together with attached hydrophobic particles, into a froth phase that forms on the cyclone axis. The froth phase is stabilized and constrained by the froth pedestal at the underflow, moved toward the vortex finder of the cyclone header, and discharged as an overflow product. Water-wetted hydrophilic particles generally remain in the slurry phase and are discharged as an underflow product through the annulus created by the froth pedestal.

During the past decade, large mechanical flotation cells, such as aeration-stirred tank reactors, have been designed, installed, and operated for mineral processing. In addition, considerable effort has been made to develop column flotation technology in the United States and elsewhere; a number have been installed in industries. Nevertheless, for both mechanical and column cells, the specific flotation capacity is generally



Air-Sparged Hydrocyclone

The SITE Program assesses but does not approve or endorse technologies.

limited to 1 to 2 tons per day (tpd) per cubic foot of cell volume. In contrast, the ASH has a specific flotation capacity of at least 100 tpd per cubic foot of cell volume.

WASTE APPLICABILITY:

Standard flotation techniques used in industrial mineral processing are effective ways of concentrating materials. However, metal value recovery is never complete. The valuable material escaping the milling process is frequently concentrated in the very fine particle fraction.

The ASH can remove fine mineral particles that are amenable to the froth flotation process. These particles are generally sulfide minerals, such as galena (lead sulfide), sphalerite (zinc sulfide) and chalcopyrite (copper-iron-sulfide). Finely-divided mining wastes containing these minerals oxidize and release the metallic elements as dissolved sulfates into the groundwater. Particularly applicable are tailings from older operations conducted before the development of froth flotation. Earlier operations recovered minerals by gravity concentration, which did not effectively capture fine particles, and left tailings with relatively large concentrations of fine sulfide minerals.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in June 1990. A pilot plant has operated for the past 4 years. The most recent pilot plant trials on tailings generated by gravity concentration have confirmed both the device's ability to recover sulfide minerals and the high throughput capacity claimed by proponents of the ASH. The SITE-sponsored test program was completed on August 12, and a journal article is pending. The pilot plant is still intact and the investigators are in search of waste sites to which the technology might be applied.

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The SITE Program assesses but does not approve or endorse technologies.

MONTANA COLLEGE OF MINERAL SCIENCE & TECHNOLOGY
(Campbell Centrifugal Jig)

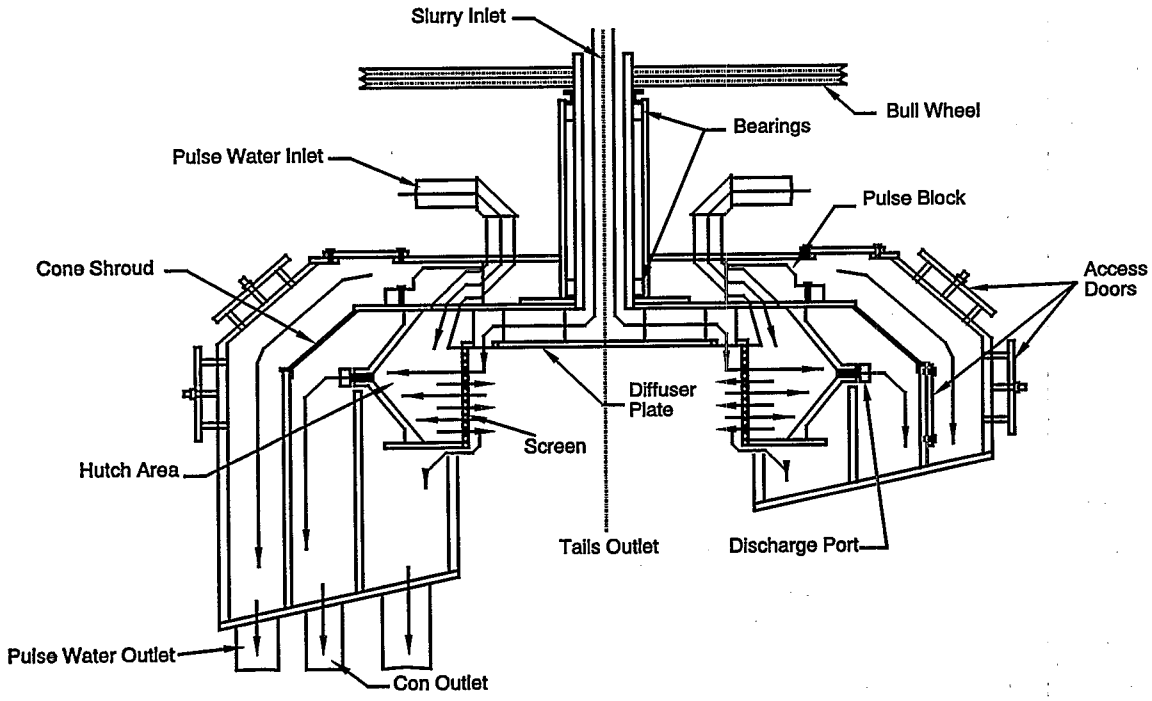
TECHNOLOGY DESCRIPTION:

The Campbell Centrifugal Jig (CCJ) is a mechanical device that uses centrifugal force to separate fine heavy mineral and metal particles from waste materials. The CCJ combines jigging and centrifuging to separate these particles from a fluid slurry. TransMar, Inc., owns the patents and rights to the CCJ technology.

Standard jigs separate solids of different specific gravities by differential settling in a pulsating bed and gravitational field. Jigs operating in this mode can recover solids larger than about 150 mesh (105 microns). Centrifuges are effective in separating solids from liquids but are not effective in separating solids from solids.

The CCJ, shown in the figure below, combines the continuous flow and pulsating bed of the standard jig with the high acceleration forces of a centrifuge to segregate and concentrate heavy particles from the waste. The CCJ can recover particles ranging in size from 1 to about 500 microns, depending on whether the particles are sufficiently disaggregated from the host material. The disaggregated particle should have a specific gravity at least 50 percent greater than the waste material. The CCJ does not need chemicals to separate the solids.

Appropriately-sized, slurried material is fed into the CCJ through a hollow shaft inlet at the top of the machine. The slurried material discharges from the shaft onto a diffuser plate, which has



Campbell Centrifugal Jig (CCJ)

The SITE Program assesses but does not approve or endorse technologies.

vanes that distribute the material radially to the jig bed. The jig bed's surface is composed of stainless-steel shot ragging that is slightly coarser than the screen aperture. The jig bed is pulsated by pressurized water admitted through a screen by four rotating pulse blocks. The pulsing water intermittently fluidizes the bed, causing heavier particles to move through the ragging and screen to the concentrate port, while lighter particles continue across the face of the jig bed to the tailings port.

The separation's effectiveness depends on how well the original solids are disaggregated from the waste material, and the specific gravity of each solid. The slurried feed material may require grinding to ensure disaggregation of the heavy metals. Operating parameters include pulse pressure, rotation speed or g-load, screen aperture, ragging type and size, weir height, and feed percent solids.

The CCJ process produces heavy mineral or metal concentrates which, depending upon the waste material, may be further processed for extraction or sale. A clean tailings stream may be returned to the environment.

WASTE APPLICABILITY:

The CCJ can separate and concentrate a wide variety of materials, ranging from base metals to fine coal ash and fine (1 micron) gold particles. Applications include 1) remediation of heavy metal-contaminated soils, tailings, or harbor areas containing spilled concentrates; 2) removal of pyritic sulfur and ash from fine coal; and 3) treatment of some sandblasting grit.

STATUS:

The CCJ was accepted into the SITE Emerging Technology Program in May 1992. The CCJ has been evaluated at the Montana College of Mineral Science and Technology Research Center (Montana Tech). Montana Tech has equipped a pilot plant to evaluate the Series 12 CCJ, which has a capacity of 1 to 3 tons per hour. Tests were completed in August 1994 on base-metal mine tailings from various locations in western Montana. A report on these tests is pending.

In addition, under the U.S. Department of Energy (DOE) Integrated Demonstration Program, the CCJ was tested on clean Nevada test site soil spiked with bismuth as a surrogate for plutonium oxide. These tests occurred at the University of Nevada, Reno, during August and September 1994. In the future, the CCJ will be tested for its capability to remove radioactive contamination from soils from several DOE sites.

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The SITE Program assesses but does not approve or endorse technologies.

NEW JERSEY INSTITUTE OF TECHNOLOGY
(GHEA Associates Process)

TECHNOLOGY DESCRIPTION:

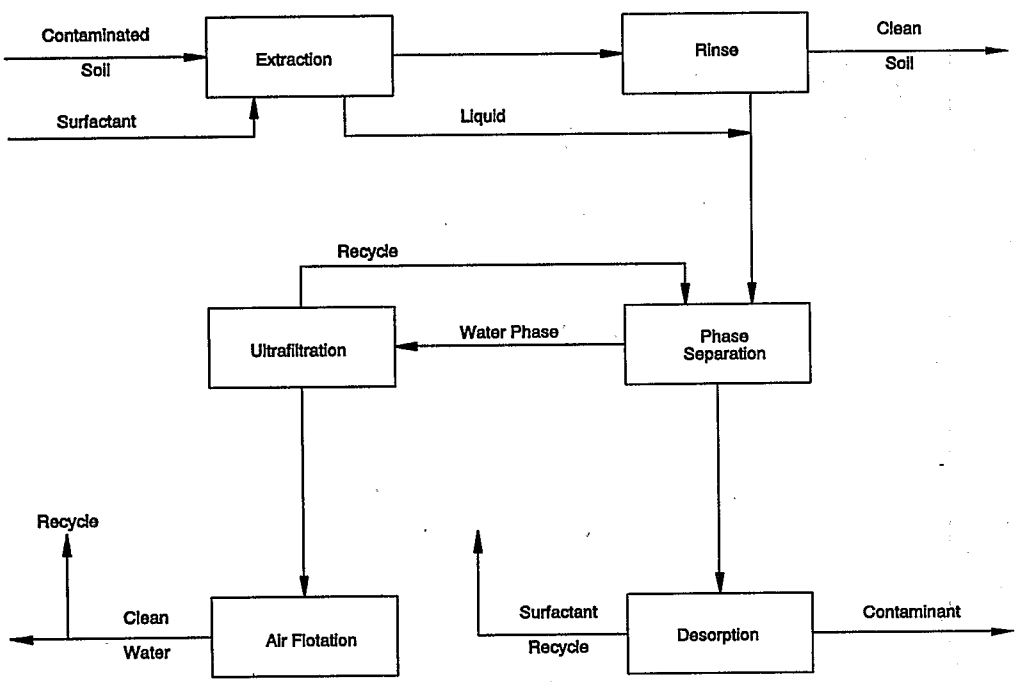
The GHEA Associates Process applies surfactants and additives to soil washing and wastewater treatment to make organic and metal contaminants soluble. In soil washing, soil is first excavated, washed, and rinsed to produce clean soil. Wash and rinse liquids are then combined and treated to separate surfactants and contaminants from the water. Next, contaminants are separated from the surfactants by desorption and isolated as a concentrate. Desorption regenerates the surfactants for repeated use in the process.

The liquid treatment consists of a sequence of steps involving phase separation, ultrafiltration, and air flotation. The treated water meets all National Pollutant Discharge Elimination System groundwater discharge criteria, allowing it to be 1) discharged without further treatment, and 2) reused in the process itself or reused as a source of high quality water for other users.

In wastewater treatment applications, surfactants added to the wastewater adsorb contaminants. The mixture is then treated in the same manner as described above for 1) water purification, 2) separation of the contaminants, and 3) recovery of the surfactants. The treatment process yields clean soil, clean water, and a highly concentrated fraction of contaminants. No other residues, effluents, or emissions are produced. The figure below illustrates the GHEA process.

WASTE APPLICABILITY:

This technology can be applied to soil, sludges, sediments, slurries, groundwater, surface water, end-of-pipe industrial effluents, and in situ soil flushing. Contaminants that can be treated include both organics and heavy metals, non-



GHEA Process for Soil Washing

The SITE Program assesses but does not approve or endorse technologies.

volatile and volatile compounds, and highly toxic refractory compounds.

STATUS:

The technology was accepted into the SITE Emerging Technology Program in June 1990. Treatability tests were conducted on various matrices, including soils with high clay contents, industrial oily sludges, industrial wastewater effluents, and contaminated groundwater (see table below). In situ soil flushing tests have shown a 20-fold enhancement of contaminant removal rates. Tests using a 25-gallon pilot-plant have also been conducted. A Bulletin (EPA/540/F-94/509) is available from EPA; a final report will be available in late 1994. Costs for treatment range from $50 to $80 per ton.

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SUMMARY OF TREATABILITY TEST RESULTS			
MATRIX	UNTREATED SAMPLE	TREATED SAMPLE	PERCENT REMOVAL
Volatile Organic Compounds (VOC): trichloroethylene; 1,2-dichloroethylene; Benzene; Toluene			
Soil, parts per million (ppm)	20.13	0.05	99.7%
Water, parts per billion (ppb)	109.0	2.5	97.8%
Total Petroleum Hydrocarbons (TPH): Soil, ppm	13,600	80	99.4%
Polychlorinated Biphenyls (PCB):			
Soil, ppm	380.00	0.57	99.8%
Water, ppb	6,000.0	<0.1	>99.9%
Trinitrotoluene in Water, ppm	180.0	<.08	>99.5%
Coal Tar Contaminated Soil (ppm):			
Benzo[a]pyrene	28.8	<0.1	>99.7%
Benzo[k]fluoranthene	24.1	4.4	81.2%
Chrysene	48.6	<0.1	>99.8%
Benzanthracene	37.6	<0.1	>99.7%
Pyrene	124.2	<0.1	>99.9%
Anthracene	83.6	<0.1	>99.8%
Phenanthrene	207.8	<0.1	>99.9%
Fluorene	92.7	<0.1	>99.9%
Dibenzofuran	58.3	<0.1	>99.8%
1-Methylnaphthalene	88.3	1.3	98.5%
2-Methylnaphthalene	147.3	<0.1	>99.9%
Heavy Metals In Soil: Chromium, ppm	21,000	640	96.8%
Iron (III) in Water, ppm:	30.8	0.3	99.0%

The SITE Program assesses but does not approve or endorse technologies.

PSI TECHNOLOGIES, A Division of Physical Sciences Inc.
(Metals Immobilization and Decontamination of Aggregate Solids)

TECHNOLOGY DESCRIPTION:

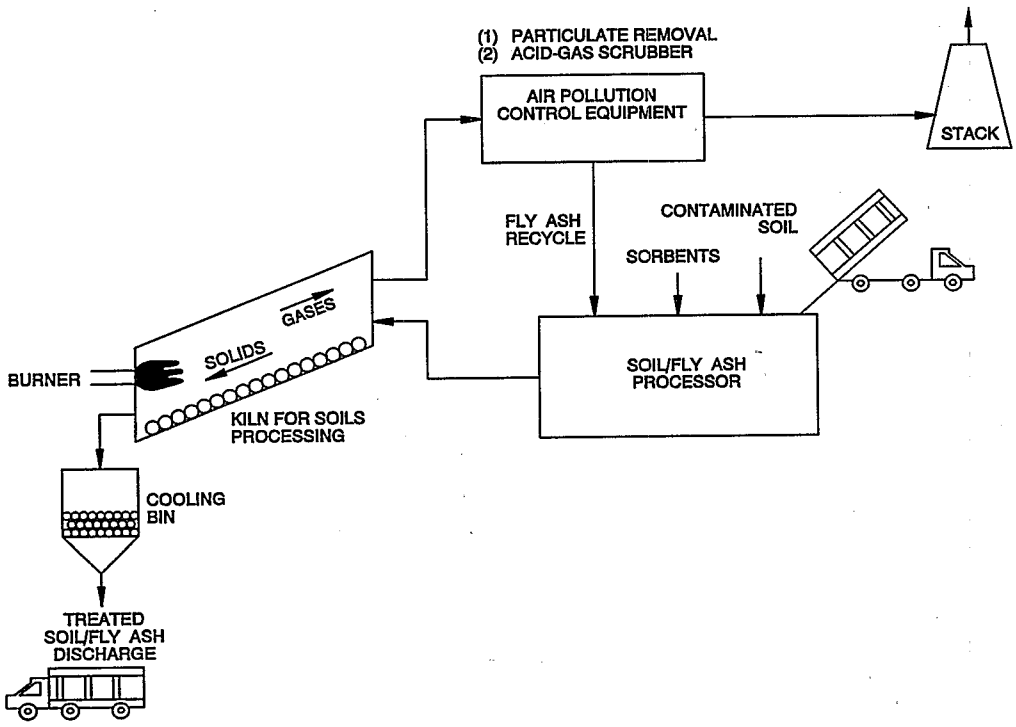
PSI Technologies has developed a metals immobilization and decontamination of aggregate solids (MeIDAS) process (see figure below). The technology involves a modified incineration process in which high temperatures destroy organic contaminants in soil and concentrate metals into fly ash. The bulk of the soil ends up as bottom ash and is rendered nonleachable. The fly ash is then treated with a sorbent to immobilize the metals, as determined by the toxicity characteristic leaching procedure. The MeIDAS process requires a sorbent fraction of less than 5 percent by soil weight.

Standard air pollution control devices clean the effluent gas stream. Hydrogen chloride and sulfur dioxide, which may be formed from the oxidation of chlorinated organics and sulfur compounds in the waste, are cleaned by alkaline scrubbers. Fly ash is captured by a particulate removal device, such as an electrostatic precipitator or baghouse. The only solid residues exiting the process are treated soils, which no longer contain organics and will not leach toxic metals.

WASTE APPLICABILITY:

The MeIDAS process treats organics and heavy metals in soils, sediments and sludges. The process has been effective in treating arsenic, cadmium, chromium, lead, nickel, and zinc.

The MeIDAS process is applicable to wastes contaminated with a combination of volatile metals and complex organic mixtures of low volatility. Possible MeIDAS process applications include battery waste sites and urban



MeIDAS Process

The SITE Program assesses but does not approve or endorse technologies.

sites containing lead paint or leaded gasoline, or a site contaminated with organometallics from disposal practices at chemical or pesticide manufacturing facilities.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1991. Initial testing, conducted under an EPA Small Business Innovative Research program, has demonstrated the feasibility of treating wastes containing arsenic, cadmium, lead, and zinc. Bench-scale testing under the SITE Program was completed in July 1992. This study demonstrated that organic, lead, and arsenic wastes could be successfully treated with less sorbent (1 to 10 percent of the soil by weight) than previously anticipated. Pilot-scale testing occurred October 1992 and was completed in May 1993. A demonstration of the MeIDAS Process is in the planning stage.

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The SITE Program assesses but does not approve or endorse technologies.

PULSE SCIENCES, INC.
(X-Ray Treatment of Aqueous Solutions)

TECHNOLOGY DESCRIPTION:

X-ray treatment of organically contaminated aqueous solutions is based on the in-depth deposition of ionizing radiation. X-rays collide with matter, generating a shower of lower energy secondary electrons within the contaminated waste material. The secondary electrons ionize and excite the atomic electrons, break up the complex contaminant molecules, and form radicals. These radicals react with the volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC) to form nontoxic by-products such as water, carbon dioxide, and oxygen.

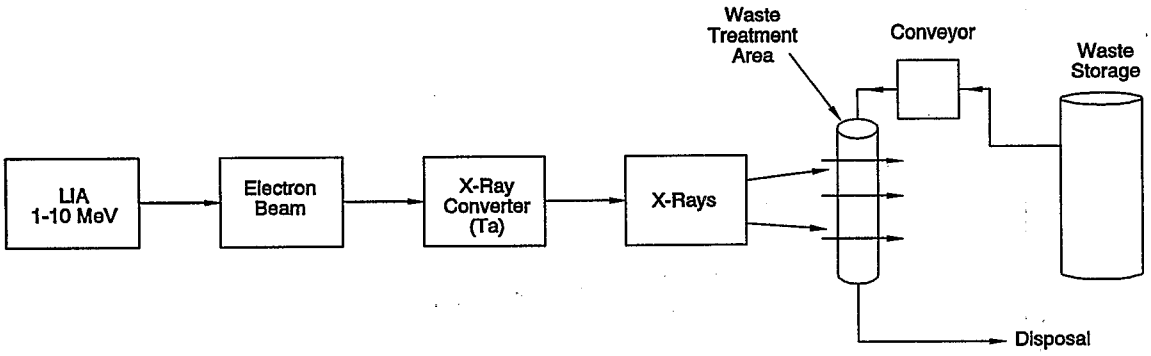
High energy X-rays and electrons transfer their energy to the background media by similar interactions, which makes X-ray processing similar to direct electron beam processing, a highly effective method used to destroy organic contaminants in aqueous solutions. The X-ray's effective penetration, however, is much deeper than that of an electron of the same energy. X-ray treatment alleviates material handling problems and allows treatment of much thicker waste volumes.

A high-power linear induction accelerator (LIA) plus X-ray converter generates the X-rays used in the treatment process (see figure below). The LIA energy is between 1 million electron volts (MeV) and 10 MeV; the upper limit depends on the application and is chosen small enough to avoid activation. A pulse of electrons 50 to 100 nanoseconds long is directed onto a cooled converter of high atomic number to efficiently generate X-rays. The X-rays then penetrate the container and waste material.

Based on coupled electron/photon Monte Carlo transport code calculations, the effective penetration depth of X-rays produced by converting 10 MeV electrons is predicted to be 32 centimeters when passed through the side of a rotating 55-gallon drum filled with water. Therefore, large contaminant volumes can be easily treated without absorbing a significant fraction of the ionizing radiation in the container walls. Either flowing waste or contaminated waste can be treated. No additives are required for the process, and in situ treatment is also feasible. Moreover, electron accelerators offer a high level of safety; the X-ray output of the LIA is easily turned off by disconnecting the electrical power. The cost of high throughput X-ray processing is estimated to be competitive with alternative processes.

WASTE APPLICABILITY:

X-ray processing can treat a large number of contaminants without expensive waste extraction or preparation. The technology has successfully treated the following contaminants:



X-Ray Treatment Process

The SITE Program assesses but does not approve or endorse technologies.

- trichloroethylene (TCE)
- tetrachloroethylene (PCE)
- chloroform
- methylene chloride
- trans and cis-1,2 dichloroethene
- 1,1,1-trichloroethane
- carbon tetrachloride
- benzene
- toluene
- ethylbenzene
- xylene
- 1,1-dichloroethane
- 1,1-dichloroethene
- 1,2- dichloroethane
- Freon

The X-ray's deep penetration and high flux allow waste to be treated in containers, flowing systems, or in situ.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in May 1991 and demonstrated in April 1994. A 1.2 MeV, 800 ampere, 55 nanosecond LIA operating at one pulse per second gave a dose rate of 5-10 rads per second. Twelve different VOCs and SVOCs found in Superfund sites were irradiated in 21 aqueous matrices. The matrices were prepared with a neat solution of the contaminant in reagent grade water. All VOC and SVOC contaminant concentrations were significantly reduced during X-ray irradiation. Contamination concentrations of 200 to 10,000 parts per billion (ppb) were reduced to less than 0.1 to 1 ppb by X-ray doses of 5 to 70 kilorads for contaminants that react strongly with the hydroxyl radical. For contaminants that did not react as strongly with the hydroxyl radical, doses of 100 to 200 kilorads were required to destroy initial concentrations of 180 to 2,000 ppb.

Two sets of experiments were completed with contaminated well water from a Superfund site located at the Lawrence Livermore National Laboratory (LLNL). Samples contaminated with 10 to 3,400 ppb were reduced to less than 2 ppb by an X-ray dose of 150 kilorads. For the more highly contaminated LLNL well water samples (10 to 5000 ppb), the dose to reduce all contaminants to less than 5 ppb was estimated to be 500 kilorads, based on experimental data.

Analysis of experiments with high concentrations of TCE and PCE (10,000 to 64,000 ppb) showed no evidence of chlorinated hydrocarbons or aldehydes during remediation of TCE and PCE. However, analysis showed formation of formic acid, which was subsequently decomposed after destruction of high concentrations of TCE and PCE.

The rate coefficients which were determined from the data, can in principle, be used to estimate the dose level required to destroy mixtures of multiple VOC contaminants and hydroxyl radical scavengers. However, based on the results of this and other programs, these estimates should be applied judiciously. Only the experimentally determined destruction curves, based on the remediation of test samples of actual mixtures, can be used with confidence at the present.

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The SITE Program assesses but does not approve or endorse technologies.

PURUS, INC.
(Photolytic Oxidation Process)

TECHNOLOGY DESCRIPTION:

The Purus, Inc. (Purus), photolytic oxidation process indirectly destroys volatile organic compounds (VOC) in soil and groundwater. The process uses a xenon pulsed-plasma flashlamp that emits short wavelength ultraviolet (UV) light at very high intensities. The process strips the contaminants into the vapor phase, and the UV treatment converts the VOCs into less hazardous compounds.

Contaminants are directly photolyzed when they absorb sufficient UV light energy, transforming electrons to higher energy states and breaking molecular bonds (see figure below). Hydroxyl radicals, however, are not formed. The process requires the UV light source to emit wavelengths in the regions absorbed by the contaminant. An innovative feature of this technology is its ability to shift the UV spectral output to optimize the photolysis.

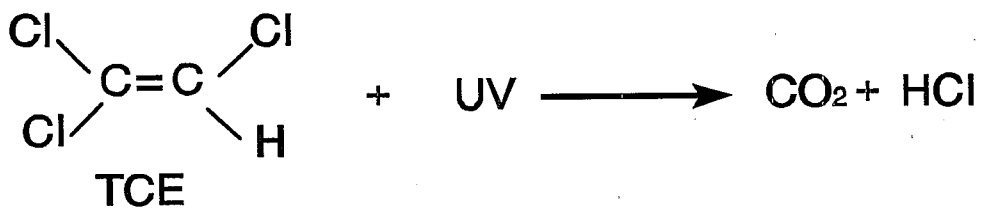
The process uses vacuum extraction or air stripping to volatilize VOCs from soils or groundwater, respectively. VOCs then enter the photolysis reactor, where a xenon flashlamp generates UV light. The plasma is produced by pulse discharge of electrical energy across two electrodes in the lamp. Ninety-nine percent destruction occurs within seconds, allowing continuous operation. Because organics are destroyed in the vapor phase, the process uses less energy than a system treating dissolved organics.

WASTE APPLICABILITY:

The Purus photolytic oxidation process is designed to destroy VOCs, including dichloroethene (DCE), tetrachloroethene (PCE), trichloroethene (TCE), and vinyl chloride volatilized from soil or groundwater. Destruction of other VOCs, such as benzene, carbon tetrachloride, and 1,1,1-trichloroethane, is under investigation.

STATUS:

The photolytic oxidation process was accepted into the SITE Emerging Technology Program in March 1991. Field testing of a full-scale prototype began in October 1991. The test was conducted at the Lawrence Livermore National Laboratory Superfund site in Livermore, California. The site contains soil zones highly contaminated with TCE. A vacuum extraction system delivered contaminated air to the Purus unit at air flows up to 500 cubic feet per minute (cfm). Initial TCE concentrations in the air were approximately 250 parts per million by volume. The contaminant removal goal for the treatment was 99 percent. Vapor phase carbon filters were placed downstream of the Purus unit to satisfy California Air Quality emission control requirements during the field test. Test results



Purus Advanced UV Photolysis

The SITE Program assesses but does not approve or endorse technologies.

are shown in the table below. The Final Report (EPA/540/R-93/516), a Summary (EPA/540/SR-93/516), and a Bulletin (EPA/540/F-93/501) have been published.

The low-wavelength UV emissions allowed direct photolysis of many VOCs, particularly chlorinated compounds and freons, that would not have been possible with commercial mercury vapor lamps. TCE, PCE, and DCE were quickly destroyed. To be rapidly photolyzed, some VOCs require photosensitization or an even lower-wavelength light source.

TCE removal yielded undesirable intermediates. Greater than 85 percent of the TCE chain photo-oxidation product is dichloroacetyl chloride (DCAC). Further oxidation of DCAC is about 100 times slower than TCE photolysis, and forms dichlorocarbonyl (DCC) at about 20 percent yield. At this treatment level, the DCC concentration may be excessive, requiring additional treatment. Further studies should focus on 1) the effectiveness of dry or wet scrubbers for removing acidic photo-oxidation products, 2) developing thermal or other methods for post-treatment of products such as DCAC, and 3) examining the use of shorter-wavelength UV lamps or catalysts to treat a broader range of VOCs. Purus will examine several of these issues with Argonne National Laboratory in continued demonstrations at the U.S. Department of Energy Savannah River site in Aiken, South Carolina.

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TCE PHOTOLYSIS FIELD TEST RESULTS

Freq. (Hz)	No. of chambers	Flow (cfm)	Res. time (sec)	TCE input (ppmv)	TCE output (ppmv)	TCE destruction (%)	DCC yield (ppmv)	DCAC yield (ppmv)	Chlorine balance (Mole%)
30	4	103	9.6	78.4	dl	≥99.99	nd	20.2	78.8
30	4	97	10.1	108.5	dl	≥99.99	21.3	26.5	106.2
30	4	95	10.4	98.3	dl	≥99.99	25.6	34	114.5
30	2	106	4.6	91.7	0.07	99.92	15.9	49.2	91.1
15	4	97	10.1	106.8	dl	≥99.99	22.8	nd	nd
15	2	103	4.8	101.3	dl	≥99.99	12.6	65.3	86.2
5	4	95	10.4	104.9	dl	≥99.99	8.7	75.7	90.0
5	2	103	4.8	101.4	dl	≥99.9	9.4	76.3	88.8
1	4	106	9.3	101.7	0.85	99.16	12.5	83.2	90.3
1	2	103	4.8	98.5	13.23	86.57	6.8	84.9	93.3

Notes: Hz = Hertz
cfm = cubic feet per minute
sec = seconds
ppmv = parts per million volume
dl = detection limit
nd = not detected

The SITE Program assesses but does not approve or endorse technologies.

J.R. SIMPLOT
(The SABRE™ Process)

TECHNOLOGY DESCRIPTION:

The J.R. Simplot Company (Simplot) Simplot Anaerobic Biological Remediation (SABRE™) Process offers a bioremediation alternative to cleaning soils and water contaminated with nitroaromatics. Nitroaromatics have become serious environmental contaminants at both private and military locations nationwide. Nitroaromatic contaminants include nitrotoluene explosives and many pesticides, including dinoseb, an herbicide banned for health concerns.

Researchers recently discovered that anaerobic microbial mixtures can completely destroy many chemicals. These chemicals include chloroform, benzene, and chlorophenols, that had been considered nonbiodegradable under such conditions.

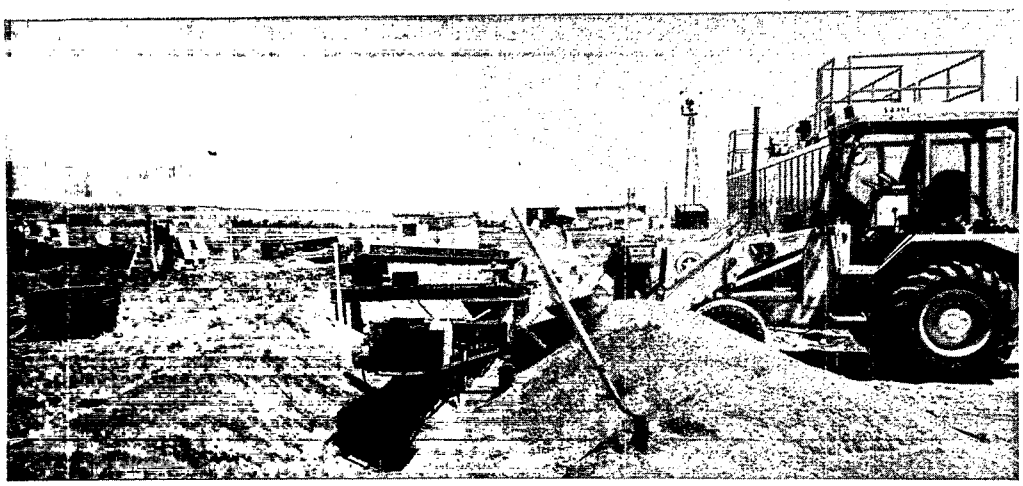
The SABRE™ Process begins when contaminated soil is placed in a bioreactor with specially prepared water in a one-to-one weight ratio. A pH buffer, a carbon source (a Simplot potato starch by-product), and a consortium of enhanced dinoseb-degrading anaerobic bacteria are introduced into the bioreactor. Research indicates that these bacteria can completely mineralize nitroaromatic contaminants.

The University of Idaho has developed anaerobic microbial mixtures for Simplot to treat the pesticide dinoseb (2-sec-butyl 4,6-dinitro-phenol) and trinitrotoluene (TNT). This mixture consists of a variety of microbial genera, including clostridia. The mixture activates a redox potential of -200 millivolts or lower.

The initial step in nitroaromatic compound metabolism is a reduction of the nitrosubstituents to amino groups, producing diaminonitro isomers. Reduction of the third nitro group occurs only under strictly anaerobic conditions. These intermediates are further degraded to simple organic compounds such as methylphloroglucinol and p-cresol. These compounds can be subsequently mineralized by indigenous aerobic bacteria.

WASTE APPLICABILITY:

The SABRE™ Process is designed to treat soils contaminated with nitroaromatic contaminants. Anaerobic microbial mixtures have been developed for the pesticide dinoseb and for TNT. These contaminants can be reduced to less than 1 part per million in most soils.



The SABRE™ Process for Remediation of Dinoseb
at Ellensburg, Washington

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

The SABRE™ Process was accepted into the SITE Emerging Technology Program in January 1990. Under the program, bench-scale processes have been developed for both dinoseb and TNT.

A pilot-scale system treated a total of 11.5 cubic yards of dinoseb-contaminated soils from a site in Idaho. An initial field test was performed on 25 kilograms of dinoseb-contaminated soil from a spill site in Ellensburg, Washington.

During bench-scale tests, soil contaminated with percent quantities of TNT was treated to below detectable limits. Degradation intermediates were monitored by liquid chromatography.

Based on these results, this technology was accepted into the SITE Demonstration Program in winter 1992.

FOR FURTHER INFORMATION:

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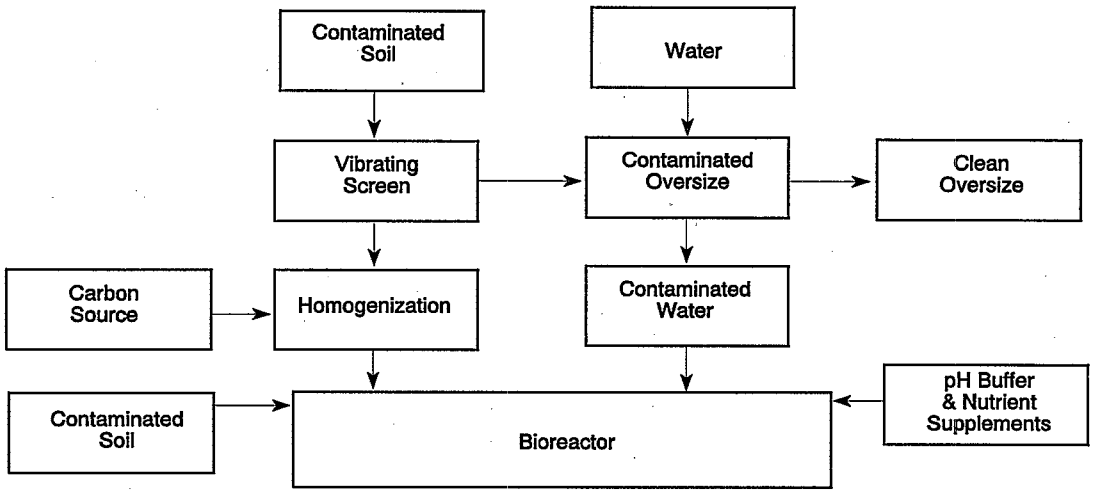
J.R. Simplot
P.O. Box 912
Pocatello, ID 83204
208-234-5367
Fax: 208-234-5339



Schematic Diagram of the SABRE™ Process

The SITE Program assesses but does not approve or endorse technologies.

TRINITY ENVIRONMENTAL TECHNOLOGIES, INC.
(PCB- and Organochlorine-Contaminated Soil Detoxification)

TECHNOLOGY DESCRIPTION:

This technology uses an aprotic solvent, other reagents, and heat to dehalogenate polychlorinated biphenyls (PCB) to inert biphenyl and chloride salts. First, solid material is sized to allow better contact between the reagents and PCBs. In a continuous flow reactor, the soils are heated to drive off excess water. Reagents are then added to destroy the PCBs.

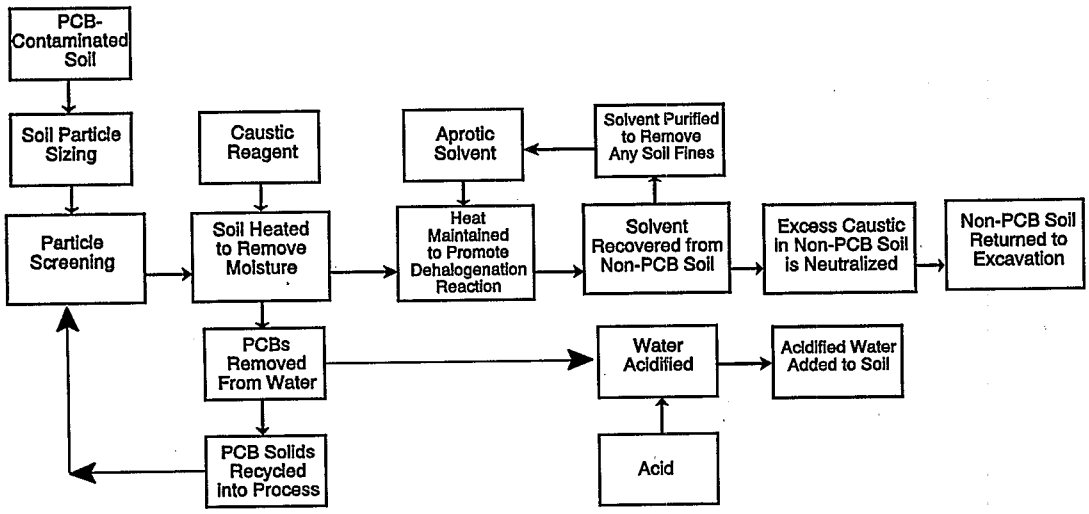
The reagent, consisting of a solvent and an inorganic alkali material, completely strips chlorine from the PCB molecule. Excess alkali can be easily neutralized. The solvent has a higher boiling point than water and is reusable in the process. Treated soil can be returned to the excavation once analytical results show that PCBs have been destroyed. Moderate processing temperatures ensure that the soil's physical structure is not appreciably changed.

Gas chromatography/mass spectroscopy analyses of processed PCB materials show that the process produces no toxic or hazardous products. A chlorine balance confirms that PCBs are completely dehalogenated. To further confirm chemical dehalogenation, inorganic and total chloride analyses are also used. The average total chloride recovery for treated soils is greater than 90 percent.

The commercial process is expected to be less costly than incineration but more expensive than land disposal. Since no stack emissions are produced, permitting the process for a remediation would be easier than incineration.

WASTE APPLICABILITY:

The process has treated PCB Aroclor mixtures, specific PCB congeners, pentachlorophenol, and individual chlorinated dioxin isomers. However, other chlorinated hydrocarbons such as pesticides, herbicides, and polychlorinated dibenzofurans could also be treated by this technology. The process can treat many different solid and sludge-type materials, provided they are compatible with the solvent.



PCB Soil Detoxification Process

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1990. The current system was developed by researchers in early 1991, after the original, aqueous, caustic-based system proved ineffective at destroying PCBs.

In bench-scale studies, synthetically contaminated materials have been processed to eliminate uncertainties in initial PCB concentration. This chemical process has reduced PCB concentrations from 2,000 parts per million (ppm) to less than 2 ppm in about 30 minutes using moderate power input. Further laboratory experiments are underway to isolate the reaction mechanism and to enhance PCB destruction. Through additional experimentation, Trinity Environmental Technologies, Inc., expects to reduce processing time through better temperature control, more efficient mixing, and possibly more aggressive reagents.

A modular pilot-scale processor has been planned that uses several heating zones to preheat and dry the contaminated soil, followed by PCB destruction. The pilot process would be capable of processing 1 ton per hour initially. Additional modules could be added to increase process capacity, as needed. Contaminated soils from actual sites will be used for these tests instead of the synthetically contaminated soils used in bench-scale testing.

The SITE project terminated in 1992. The developer is investigating further improvements to the technology. Due to cost limitations, no commercialization of the investigated process is expected. A final report will not be published.

FOR FURTHER INFORMATION:

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The SITE Program assesses but does not approve or endorse technologies.

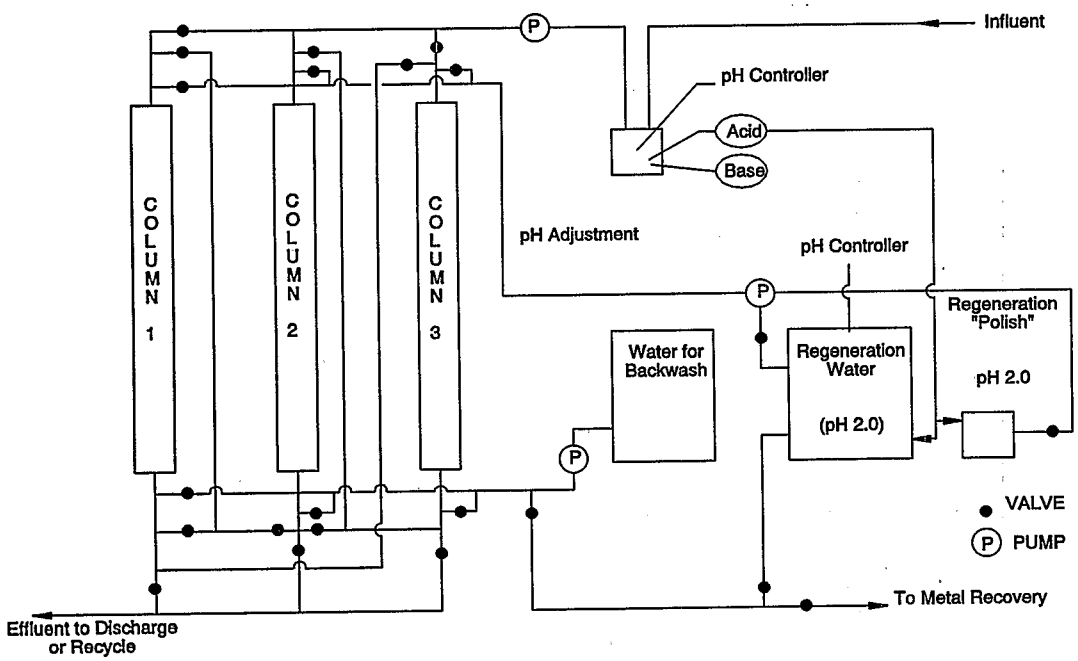
UNIVERSITY OF WASHINGTON
(Adsorptive Filtration)

TECHNOLOGY DESCRIPTION:

Adsorptive filtration removes inorganic contaminants (metals) from aqueous waste streams. An adsorbent ferrihydrite is applied to the surface of an inert substrate such as sand, which is then placed in a vertical column (see figure below). The contaminated waste stream is adjusted to a pH of 9 to 10 and passed through the column. The iron-coated sand grains in the column act simultaneously as a filter and adsorbent. When the column's filtration capacity is reached (indicated by particulate breakthrough or column blockage), the column is backwashed. When the adsorptive capacity of the column is reached (indicated by breakthrough of soluble metals), the metals are removed and concentrated for subsequent recovery with a pH-induced desorption process.

Sand can be coated with either iron nitrate or iron chloride salt, and in some cases sodium hydroxide. The resulting ferrihydrite-coated sand is insoluble at pH above about 1; thus, acidic solutions can be used in the regeneration step to ensure complete metal recovery. The system does not appear to lose treatment efficiency after numerous regeneration cycles. Anionic metals such as arsenate, chromate, and selenite can be removed from the solution by treating it at a pH near 4 and regenerating it at a high pH. The system has an empty bed retention time of 2 to 5 minutes.

This technology's advantages over conventional treatment technologies include its ability to 1) remove both dissolved and suspended contaminants from the waste stream, 2) remove a variety of complex metals, 3) work in the



Adsorptive Filtration Treatment System

The SITE Program assesses but does not approve or endorse technologies.

presence of high concentrations of background ions, and 4) remove anions.

WASTE APPLICABILITY:

This adsorptive filtration process removes inorganic contaminants, consisting mainly of metals, from aqueous waste streams. It can be applied to aqueous waste streams with a wide range of contaminant concentrations and pH values.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in January 1988. Synthetic solutions containing cadmium, copper, or lead at concentrations of 0.5 part per million (ppm) were treated in packed columns using 2-minute retention times. After approximately 5,000 bed volumes were treated, effluent concentrations were about 0.025 ppm for each metal, or a 95 percent removal efficiency. The tests were stopped, although the metals were still being removed. In other experiments, the media adsorbed about 7,000 milligrams per liter (mg/L) copper.

The first batch of regenerant solutions contained cadmium and lead at concentrations of about 500 ppm. With initial concentrations of 0.5 ppm, this represents a concentration factor of about 1,000 to 1. Data for the copper removal test have not been analyzed. At a flow rate yielding a 2-minute retention time, the test would have taken about 7 days of continuous flow operation to treat 5,000 bed volumes. Regeneration took about 2 hours.

The system has also been tested for treatment of rinse waters from a copper-etching process at a printed circuit board shop. The coated sand was effective in removing mixtures of soluble, complexed, and particulate copper, as well as zinc and lead, from these waters. When two columns were used in series, the treatment system was able to handle fluctuations in influent copper concentration from less than 10 mg/L up to several hundred mg/L.

Groundwater from Western Processing, a Superfund site near Seattle, Washington, was treated successfully to remove both soluble and particulate zinc.

The Final Report (EPA/540/R-93/515), Summary (EPA/540/SR-93/515), and Bulletin (EPA/540/F-92/008) are available from EPA.

FOR FURTHER INFORMATION:

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The SITE Program assesses but does not approve or endorse technologies.

VORTEC CORPORATION
(Oxidation and Vitrification Process)

TECHNOLOGY DESCRIPTION:

Vortec Corporation (Vortec) has developed an oxidation and vitrification process for remediating soils, sediments, sludges, and mill tailings that have organic, inorganic, and heavy metal contamination. The process can oxidize and vitrify materials introduced as dry granulated materials or slurries.

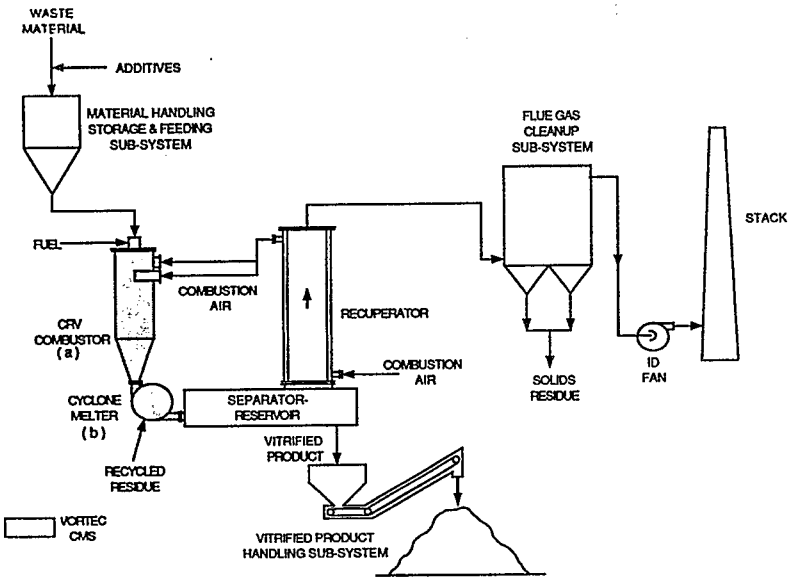
The figure below illustrates the Vortec oxidation and vitrification process. The basic elements of this system include 1) a combustion and melting system (CMS); 2) a material handling, storage, and feeding subsystem; 3) a vitrified product separation and reservoir assembly; 4) a waste heat recovery air preheater (recuperator); 5) a flue gas cleanup subsystem; and 6) a vitrified product handling subsystem.

The Vortec CMS is the primary thermal processing system and consists of two major assemblies: a counter-rotating vortex in-flight suspension preheater, and a cyclone melter. First, slurried or dry contaminated soil is introduced into the counter-rotating vortex (CRV) combustor. The CRV 1) burns the auxiliary fuel introduced directly into the CRV combustor; 2) preheats the suspended waste materials along with any glass-forming additives mixed with oil; and 3) oxidizes any organic constituents in the soil. The average temperature of materials leaving the CRV combustion chamber is between 2,200 and 2,800 degrees Fahrenheit, depending on the processed soils' melting characteristics.

The preheated solid materials exit the CRV combustor and enter the cyclone melter, where they are dispersed to the chamber walls to form a molten glass product. The vitrified, molten glass product and the exhaust gases exit the cyclone melter through a tangential exit channel and enter a glass- and gas-separation chamber.

The exhaust gases then enter an air preheater for waste heat recovery and are subsequently delivered to an air pollution control subsystem for particulate and acid gas removal. The molten glass product exits the glass- and gas-separation chamber through the tap, and is delivered to a water quench assembly for subsequent disposal.

Unique features of the Vortec oxidation and vitrification process include the following:



Vortec Oxidation and Vitrification Process

The SITE Program assesses but does not approve or endorse technologies.

- Processes solid waste contaminated with both organic and heavy metal contaminants
- Uses various fuels, including gas, oil, coal, and waste
- Handles waste quantities ranging from 5 tons per day to more than 400 tons per day
- Recycles particulate residue collected in the air pollution control subsystem back into the CMS process. These recycled materials are incorporated into the glass product, resulting in zero solid waste discharge
- Produces a vitrified product that is nontoxic according to the EPA's toxicity characteristic leaching procedure (TCLP) standards, immobilizes heavy metals, and has long-term stability

WASTE APPLICABILITY:

The Vortec oxidation and vitrification system treats soils, sediments, sludges, and mill tailings containing organic, inorganic, and heavy metal contamination. Organic materials included with the waste are successfully oxidized by the high temperatures in the combustor. The inorganic constituents in the waste material will determine the amount and type of glass-forming additives required to produce a vitrified product. This process can be modified to produce a glass cullet that consistently meets TCLP requirements.

STATUS:

The Vortec Technology was accepted into the SITE Emerging Technology Program in May 1991. Research was completed in winter 1994 and the technology has been invited to participate in the SITE Demonstration Program. The research results will be published in the *Journal of Air and Waste Management* article entitled "Vitrification of Soils Contaminated by Hazardous and/or Radioactive Waste." An Emerging Technology Summary is available from EPA.

The technology has been under development by the U.S. Department of Energy (DOE) and others since 1985. A 20-ton-per-day pilot-scale test facility has been processing nonhazardous industrial waste material since 1988; the vitrified product generated in these tests passes TCLP standards. A preliminary system with a treatment rate of up to 400 tons per day has also been designed. The pilot-scale facility processed a surrogate soil spiked with arsenic, cadmium, chromium, copper, lead, nickel, and zinc compounds. Pilot-testing with a dry, granulated feed stream was completed in June 1992, and the glass product successfully passed TCLP tests. Additional testing with a slurry feedstock was completed in 1993. Transportable systems are being designed for DOE soil remediation.

A transportable demonstration unit for treating contaminated soil will be designed in 1994; construction is scheduled for 1995. Vortec is offering commercial systems and licenses for the CMS technology.

FOR FURTHER INFORMATION:

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Fax: 610-489-3185

The SITE Program assesses but does not approve or endorse technologies.

WASTEWATER TECHNOLOGY CENTRE
(Cross-Flow Pervaporation System)

TECHNOLOGY DESCRIPTION:

Pervaporation is a process for removing volatile organic compounds (VOC) from contaminated water. Permeable membranes that preferentially adsorb VOCs are used to partition VOCs from the contaminated water. VOCs diffuse from the membrane-water interface through the membrane by vacuum. Upstream of the system's vacuum vent, a condenser traps and contains the permeating vapors, condensing the vapor to liquid while alleviating fugitive emissions. The condensed organic materials represent only a fraction of the initial wastewater volume and may be subsequently disposed of at significant cost savings. Industrial waste streams may also be treated with this process, and solvents may be recovered for reuse.

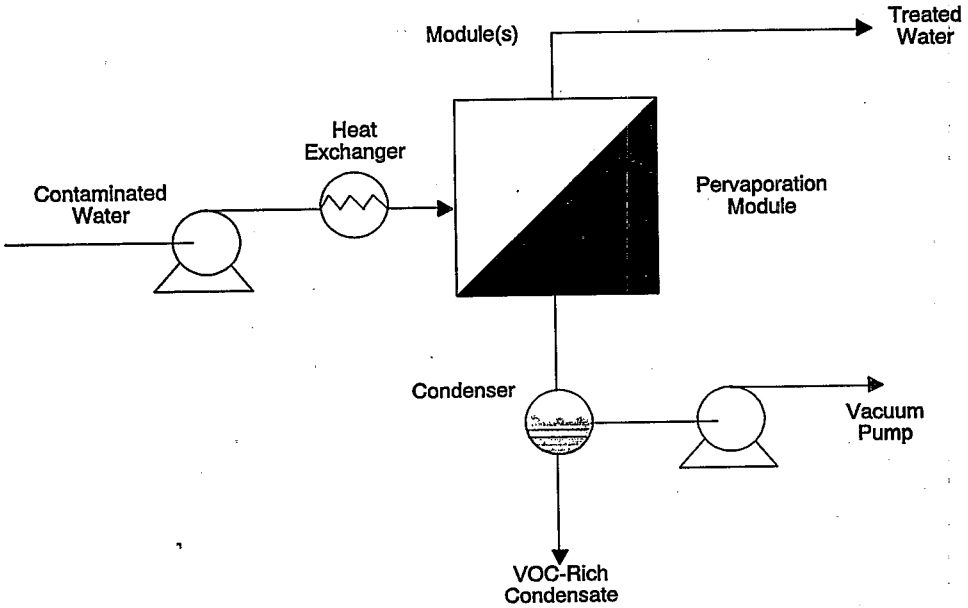
The membrane modules consist of hollow fibers with well-defined alignment that results in high mass transfer efficiencies, minimal pressure drop, and low operating costs per 1,000 gallons of treated wastewater. VOC removals have been demonstrated to less than 5 parts per billion, or better than 99.99 percent removal efficiency. High removal capacity and containment of fugitive emissions are the primary advantages of this technology, as compared to air stripping followed by gas-phase carbon adsorption.

WASTE APPLICABILITY:

Pervaporation can be applied to aqueous waste streams such as groundwater, lagoons, leachate, and rinsewater that are contaminated with VOCs such as solvents, degreasers, and gasoline. The technology is applicable to the types of wastes currently treated by carbon adsorption, air stripping, and steam stripping.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in January 1989. A cost comparison performed by the Wastewater Technology Centre in 1992 showed that pervaporation can be competitive with air stripping



Cross-Flow Pervaporation System

The SITE Program assesses but does not approve or endorse technologies.

and activated carbon to treat low VOC concentrations.

Based on results from the Emerging Technology Program, the cross-flow pervaporation system was invited to participate in the SITE Demonstration Program. A pilot system built by Zenon Environmental Inc. for Emergencies Engineering Division of Environment Canada was evaluated in-house and field tested in late 1993 in the preliminary phase of the SITE demonstration. The system removed more than 99 percent of VOCs from the wastewater. A full-scale demonstration is scheduled for 1994 at Naval Air Station North Island in San Diego, California.

A Bulletin (EPA/540/F-93/503), Summary (EPA/540/SR-94/512), and Final Report (EPA/540/R-94/512), and National Technical Information Service (PB94-170230) are available.

FOR FURTHER INFORMATION:

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Fax: 905-639-1812

The SITE Program assesses but does not approve or endorse technologies.

WESTERN RESEARCH INSTITUTE
(Contained Recovery of Oily Wastes [CROW™])

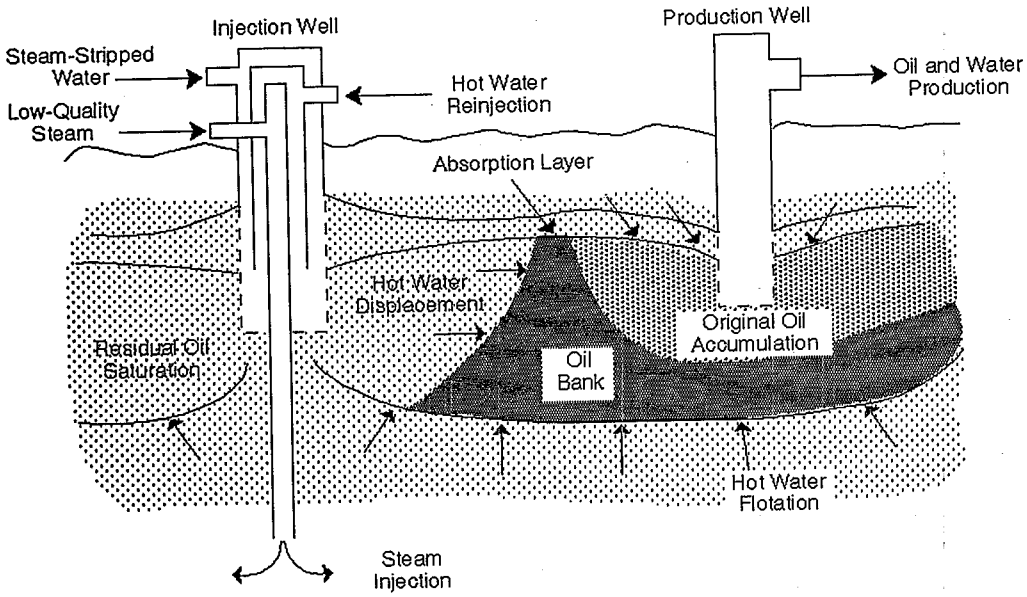
TECHNOLOGY DESCRIPTION:

The Contained Recovery of Oily Wastes (CROW™) process recovers oily wastes from the ground by adapting a technology used for secondary petroleum recovery and primary production of heavy oil and tar sand bitumen. Steam and hot water displacement move accumulated oily wastes and water to production wells for aboveground treatment.

Injection and production wells are first installed in soil contaminated with oily wastes (see figure below). Low-quality steam is then injected below the waste. The steam condenses, causing rising hot water to dislodge the waste upward into the more permeable soil regions. Hot water is injected above the impermeable soil regions to heat and mobilize the oil waste accumulations, which are recovered by hot water displacement.

The displaced oily wastes form an oil bank that the hot water injection displaces to the production well. Behind the oil bank, the oil saturation becomes immobile in the subsurface pore space. The oil and water are treated for reuse or discharge.

In situ biological treatment may follow the displacement and is continued until groundwater contaminants are no longer detected. During treatment, all mobilized organic liquids and water-soluble contaminants are contained within the original boundaries of the oily waste. Hazardous materials are contained laterally by groundwater isolation and vertically by organic liquid flotation. Excess water is treated in compliance with discharge regulations.



CROW™ Subsurface Development

The SITE Program assesses but does not approve or endorse technologies.

The process 1) removes large portions of oily waste, 2) stops the downward migration of organic contaminants, 3) immobilizes residual oily waste, and 4) reduces the volume, mobility, and toxicity of oily waste. It can be used for shallow and deep contaminated areas. The process uses mobile equipment.

WASTE APPLICABILITY:

This technology can treat wastes from manufactured gas plant sites, wood-treating sites, and other sites with soils and aquifers containing light to dense organic liquids, such as coal tars, pentachlorophenol solutions, chlorinated solvents, creosote, and petroleum by-products. Depth to the contamination is not a limiting factor.

STATUS:

This technology was tested both at the laboratory- and pilot-scale under the SITE Emerging Technology Program. These tests showed the effectiveness of the hot water displacement and displayed the benefits of including chemicals with the hot water. Evaluation under the Emerging Technology Program is complete, and the final report has been submitted to EPA.

Based on the results of the Emerging Technology Program, this technology was invited to participate in the SITE Demonstration Program. The technology is being demonstrated at the Pennsylvania Power and Light (PP&L) Brodhead Creek site in Stroudsburg, Pennsylvania. The project should be completed in early 1995.

Remediation Technologies, Inc., is participating in the project. Other sponsors, in addition to EPA and PP&L, are the Gas Research Institute, the Electric Power Research Institute, and the U.S. Department of Energy.

This technology has been demonstrated at the pilot scale at a wood treatment site in Minnesota outside of the SITE Program. A 2-year full-scale remediation program is presently underway at this site. The developer is conducting screening studies for additional sites and is investigating the use of chemicals with the hot water displacement. Nonaqueous phase liquid removal rates of 60 to over 80 percent have been achieved with hot water injection. Chemical addition significantly increased recovery.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
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The SITE Program assesses but does not approve or endorse technologies.

TABLE 4

Ongoing SITE Emerging Technology Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
ABB Environmental Services, Inc., Wakefield, MA (E07)*	Anaerobic/Aerobic Sequential Bioremediation of PCE	Willard Murray 617-245-6606	Ronald Lewis 513-569-7856	Groundwater	Not Applicable	PCE, TCE, Vinyl Chloride
Arizona State University/ IT Corporation, Tempe, AZ/Knoxville, TN (E06)	Photocatalytic Oxidation with Air Stripping	Gregory Raupp 602-965-2828 Richard Miller 615-690-3211	Norma Lewis 513-569-7665	Air Streams	Not Applicable	VOCs
Atomic Energy of Canada Limited, Chalk River, Ontario, Canada (E06)	Ultrasonic-Aided Leachate Treatment for Mixed Wastes	S. Vijayan and L. A. Moschuk 613-584-3311 Phil Campbell 800-872-2325	Joan Mattox 513-569-7624	Acid Mine Drainage	Heavy Metals, Radionuclides	Not Applicable
Center for Hazardous Materials Research, Pittsburgh, PA (E05)	Organics Destruction and Metals Stabilization	Bruce King 412-826-5320	Randy Parker 513-569-7271	Soil, Sediment	Heavy Metals	Nonspecific Organics
COGNIS, Inc., Santa Rosa, CA (E05)	Biological/Chemical Treatment	Ron Wilson 707-576-6231	Steven Rock 513-569-7149	Soil	Heavy Metals	PAHs, Petroleum Hydrocarbons
Davy International Energy and Environmental Division (formerly Davy Research and Development, Limited), Stockton-on-Tees, England (E04)	Chemical Treatment	Graham Wightman 011-44-642-602221	Mary Stinson 908-321-6683	Soil, Sediment	Heavy Metals	Chlorinated Solvents, Pesticides, PCBs
M.L. ENERGIA, Inc., Princeton, NJ (E05)	Reductive Photo-Dechlorination Treatment	Moshe Lavid 609-799-7970	Michelle Simon 513-569-7469	Liquid, Gas	Not Applicable	Volatile Chlorinated Wastes
M.L. ENERGIA, Inc., Princeton, NJ (E07)	Reductive Thermal and Photo-Thermal Oxidation Processes for Enhanced Conversion of Chlorocarbons	Moshe Lavid 609-799-7970	Michelle Simon 513-569-7469	Air	Not Applicable	Volatile Hydrocarbons

* Solicitation Number

TABLE 4 (continued)

Ongoing SITE Emerging Technology Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Energy and Environmental Research Corporation, Irvine, CA (E06)	Reactor Filter System	Wm. Randall Seeker 714-859-8851	Joyce Perdek 908-321-4380	Gas Streams	Volatile Toxic Metals	Condensed-Phase Organics
Environmental BioTechnologies, Inc., Menlo Park, CA (E06)	Microbial Composting Process	Douglas Munnecke 415-462-6712	Ronald Lewis 513-569-7856	Soil, Sediment	Not Applicable	Coal Tar Wastes, PAHs
General Atomics, Nuclear Remediation Technologies Division, San Diego, CA (E06)	Acoustic Barrier Particulate Separator	Robert Goforth 619-455-2499	Laurel Staley 513-569-7863	Gas Streams	Radioactive Particles	SVOCs, PCBs
Geo-Microbial Technologies, Inc., Ochelata, OK (E07)	Metals Release and Removal from Wastes	Donald Hitzman 918-535-2281	Jack Hubbard 513-569-7507	Soil, Sludge, Sediment	Metals	Hydrocarbons, Other Organic Pollutants
Groundwater Technology Government Services, Inc., Concord, CA (E04)	Below-Grade Bioremediation of Chlorinated Cyclodiene Insecticides	Rod Venterea 510-671-2116	Ronald Lewis 513-569-7856	Soil, Sludge, Sediment	Not Applicable	Biodegradable Organic Compounds
High Voltage Environmental Applications, Inc., Miami, FL (E06)	High Energy Electron Beam Irradiation	William Cooper 305-593-5330	Mary Stinson 908-321-6683	Soil, Sediment, Sludge	Not Applicable	Pesticides, Insecticides, Petroleum Residues, PCBs
Institute of Gas Technology, Des Plaines, IL (E03)	Fluidized-Bed Cyclonic Agglomerating Combustor	Amir Rehmat 708-768-0588 Michael Mensinger 708-768-0602	Teri Richardson 513-569-7949	Solid, Liquid, Gas, Soil, Sludge	Nonvolatile Inorganics	Nonspecific Organics
Institute of Gas Technology, Des Plaines, IL (E07)	Supercritical Extraction/Liquid Phase Oxidation	Michael Mensinger 708-768-0602	Annette Gatchett 513-569-7697	Soil, Sludge	Not Applicable	PAHs, PCBs
IT Corporation, Cincinnati, OH (E07)	Chelation/Electro-deposition of Toxic Metals from Soils	E. Radha Krishnan 513-782-4700	George Moore 513-569-7991	Soil, Sludge	Metals	Not Applicable
IT Corporation, San Bernardino, CA (E06)	Eimco Biolift™ Slurry Reactor	Kandi Brown 909-799-6869	Brunilda Davila 513-569-7849	Soil, Sludge	Not Applicable	PAHs
IT Corporation, Knoxville, TN (E04)	Mixed Waste Treatment Process	Ed Alperin 615-690-3211	Douglas Grosse 513-569-7844	Soil	Nonspecific Inorganics, Radioactive Material	Nonspecific Organics

TABLE 4 (continued)

Ongoing SITE Emerging Technology Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Lewis Environmental Services, Inc./Hickson Corporation, Pittsburgh, PA (E06)	Chromated Copper Arsenate Soil Leaching Process	Tom Lewis III 412-322-8100	Randy Parker 513-569-7271	Soil	Heavy Metals, Nonspecific Inorganics	Nonspecific Organics
Matrix Photocatalytic Inc. (formerly Nutech Environmental),** London, Ontario, Canada (E05)	TiO_2 Photocatalytic Air Treatment	Bob Henderson 519-660-8669	John Ireland 513-569-7413	Air	Not Applicable	VOCs
Membran Corporation, Minneapolis, MN (E07)	Membrane Gas Transfer in Waste Remediation	Charles Gantzer 612-378-2160	Paul dePercin 513-569-7797	Air	Not Applicable	Petroleum Hydrocarbons, Chlorinated Solvents
OHM Remediation Services Corporation, Findlay, OH (E05)	Oxygen Microbubble In Situ Bioremediation	Douglas Jerger 419-424-4932	Ronald Lewis 513-569-7856	Groundwater	Not Applicable	Petroleum Hydrocarbons, Organic Solvents, Creosote, PCP
Pulse Sciences, Inc., San Leandro, CA (E06)	X-Ray Treatment of Organically Contaminated Soils	Vernon Bailey 510-632-5100	George Moore 513-569-7991	Soil	Not Applicable	Benzene, Toluene, Xylene, TCA, TCE, Carbon Tetrachloride, Chloroform, PCBs
Remediation Technologies, Inc., Seattle, WA (E05)	Chlorinated Gas Treatment Biofilm Reactor	Hans Stroo 206-624-9349	Ronald Lewis 513-569-7856	Gas	Not Applicable	Chlorinated Volatile Hydrocarbons
State University of New York at Oswego, Oswego, NY (E06)	Photocatalytic Degradation of PCB-Contaminated Sediments and Waters	Ronald Scrudato and Jeffrey Chiarenzelli 315-341-3639	Hector Moreno 513-569-7882	Soil, Sludge, Sediment	Not Applicable	PCBs, Other Chlorinated Organics, VOCs, SVOCs
Thermo Analytical, Oak Ridge, TN (E07)	Segmented Gate System (SGS)	Jeffrey Brown 615-481-0683	Joan Mattox 513-569-7624	Soil, Sludge, Sediment, Sand	Radionuclides	Not Applicable
University of Dayton Research Institute, Dayton, OH (E05)	Photothermal Detoxification Unit	Barry Dellinger and John Graham 513-229-2846	Chien Chen 908-906-6985	Soil, Sludge, Sand, Aqueous Streams	Not Applicable	PCBs, PCDDs, PCDFs, Aromatic and Aliphatic Ketones, Aromatic and Chlorinated Solvents

** Invited to participate in the SITE Demonstration Program

TABLE 4 (continued)

Ongoing SITE Emerging Technology Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
University of Houston, Houston, TX (E07)	Concentrated-Chloride Extraction and Recovery of Lead	Dennis Clifford 713-743-4266 Tim Newed 713-743-4292	Eugene Harris 513-569-7862	Soil	Lead	Not Applicable
University of South Carolina, Columbia, SC (E03)	In Situ Mitigation of Acid Water	Frank Caruccio 803-777-4512	Roger Wilmoth 513-569-7509	Acid Mine Drainage	Most Metals	Not Applicable
Western Product Recovery Group, Inc., Houston, TX (E04)	CCBA Physical and Chemical Treatment	Donald Kelly 713-493-9321	Mark Meckes 513-569-7348	Wastewater, Soil, Sludge, Sediment	Heavy Metals	Nonspecific Mixed Organics
Roy F. Weston, Inc., West Chester, PA (E06)	Ambersorb® 563 Adsorbent	Russ Turner 610-701-3097 Deborah Plantz 215-641-7478	Ronald Turner 513-569-7775	Water	Not Applicable	VOCs

ABB ENVIRONMENTAL SERVICES, INC.
(Anaerobic/Aerobic Sequential Bioremediation of PCE)

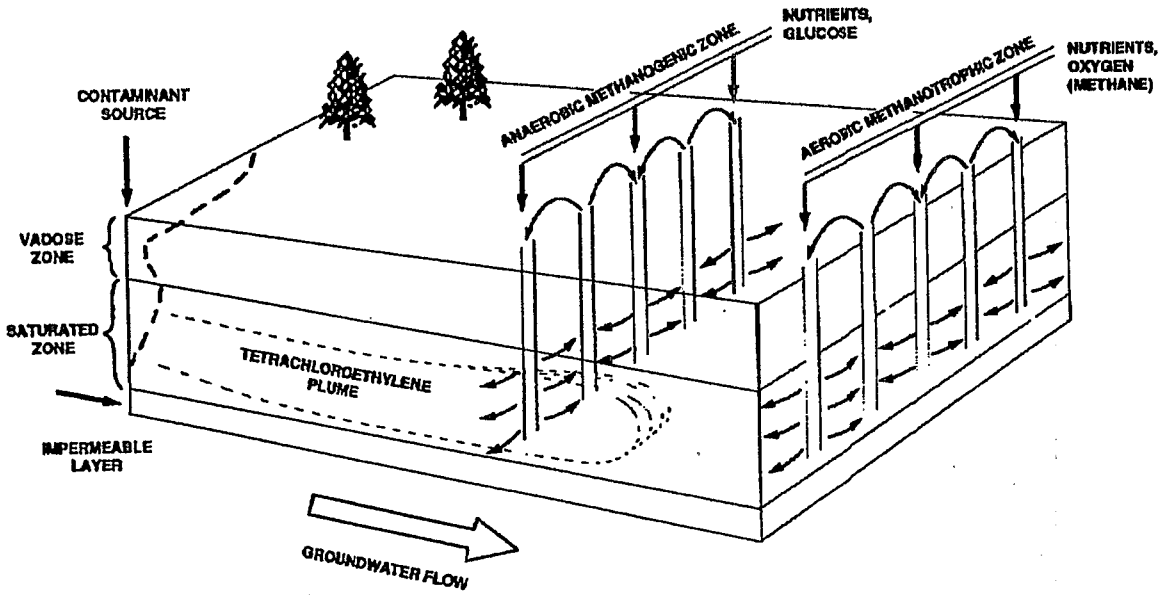
TECHNOLOGY DESCRIPTION:

ABB Environmental Services, Inc.'s (ABB-ES), research has demonstrated that sequential anaerobic/aerobic biodegradation of tetrachloroethylene (PCE) is feasible if the proper conditions can be established. The anaerobic process can potentially completely dechlorinate PCE. However, conversion of vinyl chloride (VC) to ethylene is the slowest step in this process. Of the chlorinated ethenes, VC is the most amenable to treatment by aerobic methanotrophic processes. Therefore, a two-step process is thought to be the most efficient. The first step is anaerobic, which rapidly dechlorinates PCE and trichloroethylene (TCE) to breakdown products 1,2-dichloroethylene (DCE) and VC. Since the anaerobic dechlorination of DCE and VC to ethylene can be quite slow, a second aerobic step is implemented that can more quickly complete the remediation process. The schematic diagram below illustrates this technology.

The goal of this project is to field test the effectiveness of creating and maintaining the proper in situ conditions for chlorinated ethene degradation in an aquifer. To achieve this goal, ABB-ES will test methods of carbon and mineral nutrient injection and delivery into an aquifer contaminated with PCE or TCE. Groundwater chemical conditions will be monitored within and downgradient of the anaerobic treatment zone to gauge the efficiency of the anaerobic process. If volatile organic compound analyses show that the resulting downgradient breakdown products include TCE, DCE, or VC, oxygen and methane will be added to the groundwater to stimulate aerobic degradation by indigenous methanotrophic bacteria.

WASTE APPLICABILITY:

This technology removes PCE, TCE, DCE, and VC from groundwater.



Schematic Diagram of the Anaerobic/Aerobic Sequential Bioremediation of PCE

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1994.

FOR FURTHER INFORMATION:

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Risk Reduction Engineering Laboratory
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TECHNOLOGY DEVELOPER CONTACT:
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The SITE Program assesses but does not approve or endorse technologies.

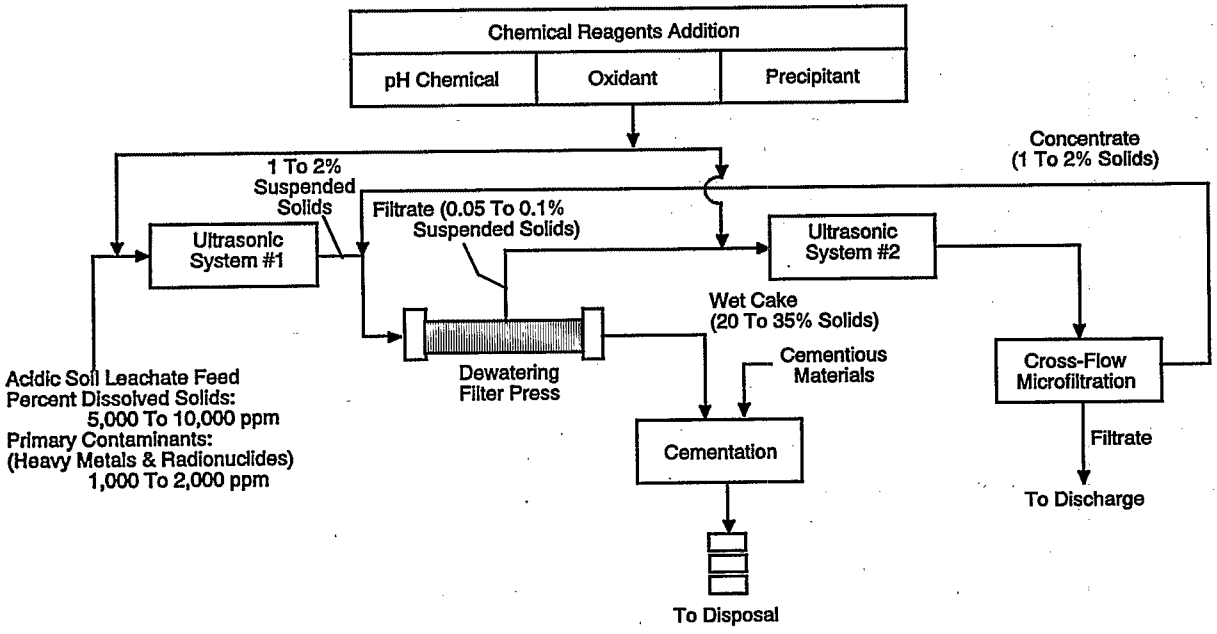
ATOMIC ENERGY OF CANADA LIMITED
(Ultrasonic-Aided Leachate Treatment for Mixed Wastes)

TECHNOLOGY DESCRIPTION:

The ultrasonic-aided leachate treatment process involves enhanced chemical treatment of acidic soil leachate solutions. These solutions, also known as acid mine drainage, are caused by the oxidation and dissolution of sulfide-bearing wastes, which produces sulfuric acid. The resulting acidic water leaches metal contaminants from the exposed waste rock and tailings, creating large volumes of acidic leachates.

The ultrasonic-aided leachate treatment uses an ultrasonic field to improve contaminant removal through precipitation, coprecipitation, oxidation, ion scavenging, and sorption (see figure below). These processes are followed by solid-liquid separation by filtration equipment using a filter press and a cross-flow microfilter connected in series. The time required for treatment depends on 1) the nature of acidic waste to be treated, 2) the treated water quality with respect to contaminant concentration, and 3) the rate at which the physical and chemical processes occur. The treatable leachate volume is scalable.

The major difference between this technology and conventional processes is the use of ultrasonic mixing instead of mechanical agitation in large tanks. Research indicates that an ultrasonic field significantly increases the conversion rate of dissolved contaminants to precipitates and the rate of oxidation and ion exchange. Earlier studies by Atomic Energy of Canada Limited



Ultrasonic-Aided Leachate Treatment
for Acidic Soil Leachate Solutions

The SITE Program assesses but does not approve or endorse technologies.

(AECL) revealed that the time required to precipitate heavy metals from aqueous solutions decreased by an order of magnitude in the presence of an ultrasonic field.

The ultrasonic-aided leachate treatment process is compact, portable, and energy-efficient. Safety and process controls are built in as necessary for handling mixed radioactive solutions. This process also generates minimal fugitive emissions and produces a treated effluent that meets applicable discharge limits. The process may be able to treat waste containing small amounts of dissolved or suspended organics.

WASTE APPLICABILITY:

The ultrasonic-aided leachate treatment process treats acid mine drainage contaminated with heavy metals and radionuclides. The process can also combine with soil and groundwater remediation technologies.

STATUS:

The ultrasonic-aided leachate treatment process was accepted into the SITE Emerging Technology Program in 1993. Under this program, AECL plans to develop and test a pilot-scale unit to treat acidic soil leachate solutions containing low levels of metals and radionuclides.

AECL plans to use waste from the Nordic Mine Tailings site near Elliot Lake, Ontario, Canada, and the Berkeley Pit near Butte, Montana in its research.

FOR FURTHER INFORMATION:

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Phil Campbell
AECL Technologies
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800-872-2325
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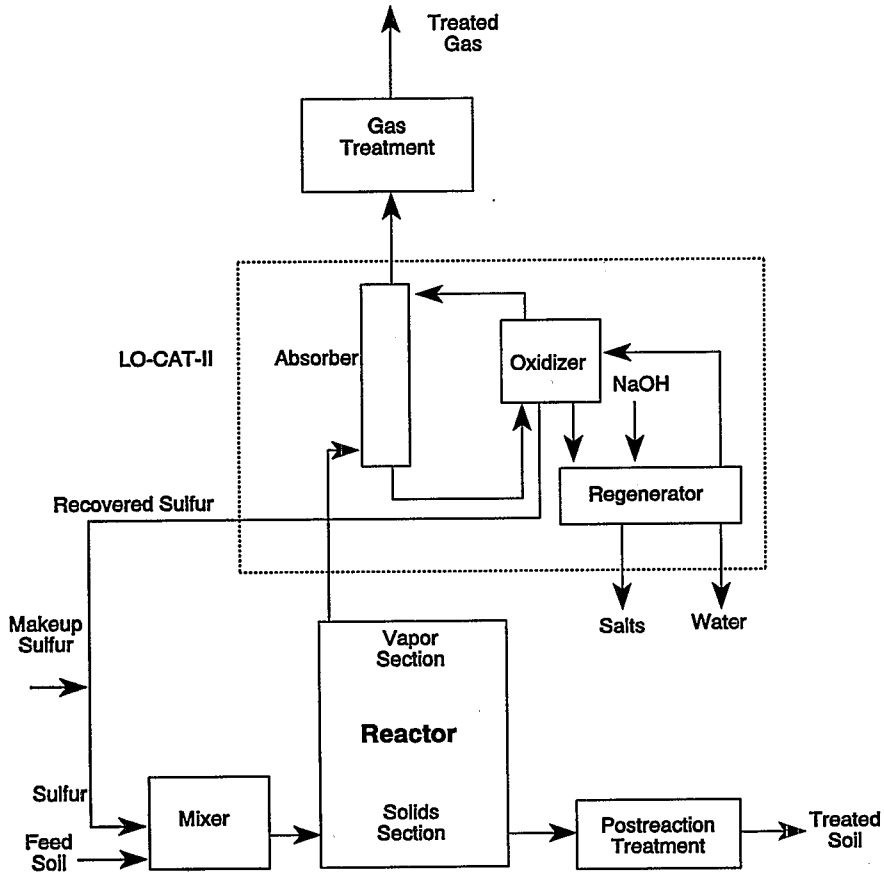
The SITE Program assesses but does not approve or endorse technologies.

CENTER FOR HAZARDOUS MATERIALS RESEARCH
(Organics Destruction and Metals Stabilization)

TECHNOLOGY DESCRIPTION:

This technology is designed to destroy hazardous organics in soils while simultaneously stabilizing metals and metal ions (see figure below). The technology causes contaminated liquids, soils, and sludges to react with elemental sulfur at elevated temperatures, since all organic compounds react with sulfur. Hydrocarbons are converted to an inert carbon-sulfur powdered residue and hydrogen sulfide gas. Treated chlorinated hydrocarbons also produce hydrochloric acid gas. These acid gases are recovered from the off-gases, and sulfur recovered for reuse by oxidation of the hydrogen sulfide in a conventional acid gas treating unit (such as ARI Technologies LO-CAT™).

In addition to destroying organic compounds, the technology converts heavy metals to sulfides, which are rendered less leachable. If required, the sulfides can be further stabilized before disposal. Thus, this process offers the potential to stabilize heavy metals in the same process step as the organics destruction.



Organics Destruction and Metals Stabilization

The SITE Program assesses but does not approve or endorse technologies.

The technology's main process components include the following:

- A prereaction mixer where the solid and reagent are mixed
- An indirectly heated, enclosed reactor that includes a preheater section to drive off water, and two integrated reactor sections to react liquid sulfur with the solids and further react desorbed organic compounds with vapor phase sulfur
- An acid gas treatment system that removes the acid gases and recovers sulfur by oxidizing the hydrogen sulfide
- A treated solids processing unit that recovers excess reagent and prepares the treated product to comply with on-site disposal requirements

Initial pilot-scale testing of the technology has demonstrated that organic contaminants can be destroyed in the vapor phase with elemental sulfur. Tetrachlorethene, trichloroethene, and polychlorinated biphenyls were among the organic compounds destroyed.

Batch treatability tests of contaminated soil mixtures have demonstrated organics destruction and immobilization of various heavy metals. Immobilization of heavy metals is determined by the concentration of the metals in leachate compared to the EPA toxicity characteristic leaching procedure (TCLP) regulatory limits. Following treatment, cadmium, copper, lead, nickel, and zinc were significantly reduced compared to TCLP values. In treatability tests with approximately 700 parts per million of Aroclor 1260, destruction levels of 99.0 to 99.95 percent were achieved.

The experimental program currently in progress is providing a more detailed definition of the process limits, metal concentrations, and soil types for stabilization of various heavy metals to meet the limits specified by TCLP. In addition, several process enhancements have been identified and are being evaluated to expand the range of applicability.

WASTE APPLICABILITY:

The technology is applicable to soils and sediments contaminated with both organics and heavy metals.

STATUS:

This technology was accepted into the SITE Emerging Technology Program and work began in January 1993. Bench-scale testing in batch reactors was completed in 1993. The current pilot-scale program is directed at integrating the process concepts and obtaining process data in a continuous unit. This program is scheduled to be completed in early 1995.

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The SITE Program assesses but does not approve or endorse technologies.

COGNIS, INC.
(Biological/Chemical Treatment)

TECHNOLOGY DESCRIPTION:

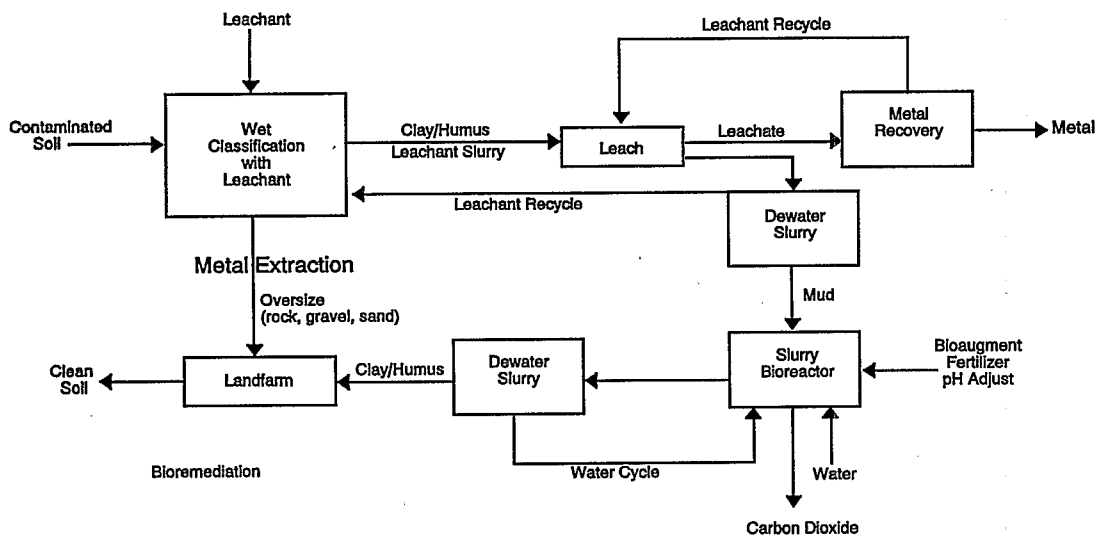
COGNIS, Inc.'s, biological/chemical treatment is a two-stage process that treats contaminated soils, sediments, and other media containing both metals and organics. Metals are first removed from the contaminated matrix by a chemical leaching process. The organics are then removed by bioremediation.

Although metals removal usually occurs in the first stage, bioremediation may be performed first if organic contamination levels are found to inhibit the metals extraction process. Bioremediation is more effective if the metal concentrations in the soil are sufficiently low so as not to inhibit the microbial population. However, even in the presence of inhibitory metal concentrations, a microbe population may be enriched to perform the necessary bioremediation.

The soil handling requirements for both stages are similar, so the unit operations are fully reversible. The final treatment products are a recovered metal or metal salt, biodegraded organic compounds, and clean soil.

The contaminated soil is first exposed to a leachant solution and classified by particle size (see figure below). Size classification allows oversized rock, gravel, and sand to be quickly cleaned and separated from the sediment fines (silt, clay, and humus), which require longer leaching times. Typically, organic pollutants are also attached to the fines.

After dissolution of the metal compounds, the metal ions, such as zinc, lead, and cadmium, are removed from the aqueous leachate by liquid ion exchange, resin ion exchange, or reduction. At this point, the aqueous leaching solution is freed of metals, and can be reused to leach additional metal from the contaminated soil. If an extraction agent is used, it is later stripped of the bound metal under conditions in which the agent is fully regenerated and recycled. The heavy metals are recovered in a saleable, concentrated form as solid metal or a metal salt. The method of metals recovery depends on the metals present and their concentrations.



Metal Leaching and Bioremediation Process

The SITE Program assesses but does not approve or endorse technologies.

After metals extraction is complete, the "mud" slurry settles and is neutralized. Liquids are returned to the classifier, and the partially treated soil is transferred to a slurry bioreactor, a slurry-phase treatment lagoon, or a closed land treatment cell for bioremediation. This soil and residual leachate solution are treated to maximize contaminant biodegradation. Micro-nutrients are added to support microbial growth, and the most readily biodegradable organic compounds are aerobically degraded.

Bench-scale tests indicate that this process can remediate a variety of heavy metals and organic pollutants. The combined process is less expensive than separate metal removal and organic remediation.

WASTE APPLICABILITY:

This remediation process can treat combined-waste soils contaminated by heavy metals and organic pollutants. The process can treat contaminants including lead, cadmium, zinc, and copper, as well as petroleum hydrocarbons and polynuclear aromatic hydrocarbons that are subject to aerobic microbial degradation. The combined process can also be modified to extract mercury and other metals, and degrade more recalcitrant halogenated hydrocarbons.

STATUS:

This remediation process was accepted into the SITE Emerging Technology Program in August 1992. Bench- and pilot-scale testing of the bioremediation process is under way. A full-scale field test of the metals extraction process is in progress.

FOR FURTHER INFORMATION:

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The SITE Program assesses but does not approve or endorse technologies.

DAVY INTERNATIONAL ENERGY AND ENVIRONMENTAL DIVISION
(formerly DAVY RESEARCH AND DEVELOPMENT, LIMITED)
(Chemical Treatment)

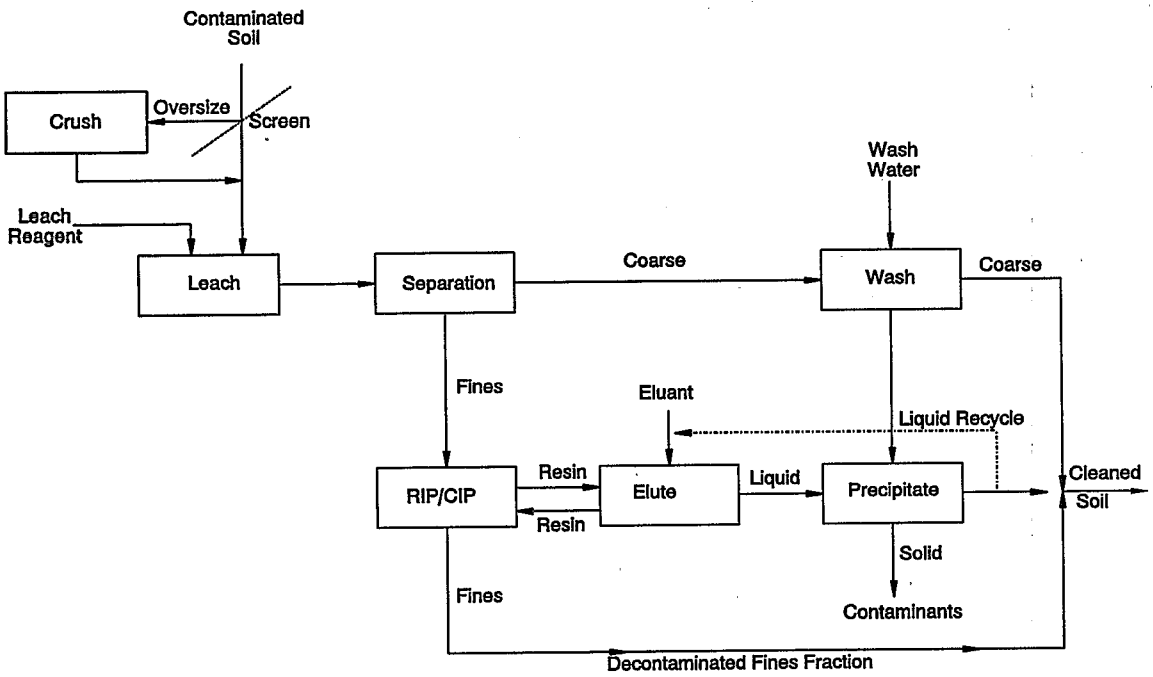
TECHNOLOGY DESCRIPTION:

This treatment employs resin-in-pulp (RIP) or carbon-in-pulp (CIP) technologies to treat soils, sediments, dredgings, and solid residues contaminated with organic and inorganic material. These technologies are based on resin ion exchange and resin or carbon adsorption of contaminants from a leached soil-slurry mixture.

RIP and CIP processes are used on a commercial scale to recover metals from ores. The RIP process is well established in the recovery of uranium and uses anion exchange resins to adsorb uranium ions leached from ore. The CIP process is commonly used to recover precious metals. In this process, activated carbon adsorbs gold and silver leached as cyanide complexes.

The figure below illustrates the process for metals and other inorganically contaminated soils. Incoming material is screened, and oversized material is crushed. The two fractions are then combined and leached in an agitated tank, where the contaminants are extracted. The leached solids are then passed to cyclones that separate coarse and fine material. The coarse material is washed free of contaminants, and the wash liquors containing the contaminants are passed to the contaminant recovery section. The leached fine fraction passes to the RIP or CIP contactor, where ion exchange resins or activated carbon remove the contaminants. The difficult fines washing step is thereby eliminated.

The resins and carbons are eluted and recycled in the extraction step, and the concentrated contaminants in the eluate pass to the recovery section. In the recovery section, precipitation recovers contaminants from the wash and eluate solutions. The precipitation yields a concentrated solid material and can be disposed of or



Chemical Treatment Process

The SITE Program assesses but does not approve or endorse technologies.

treated to recover metals or other materials. The liquid effluent from the recovery section can be recycled to the process.

For organically contaminated feeds, the in-pulp or slurry process treats the whole leached solid. Organic contaminants eluted from the resin or carbon should be treated appropriately.

Both the RIP and CIP commercial scale processes operate in multistage, continuous, countercurrent contactors arranged horizontally.

WASTE APPLICABILITY:

This chemical treatment technology treats soils and other materials contaminated with inorganic and organic wastes. Inorganics include heavy metals such as copper, chromium, zinc, mercury, and arsenic. Potential applications include treatment of materials containing organics such as chlorinated solvents, pesticides, and polychlorinated biphenyls by selecting appropriate extractant reagents and sorbent materials.

STATUS:

Davy International Energy and Environmental Division has developed proprietary RIP and CIP processes that are more compact and easier to use than conventional equipment. The size of a plant can be reduced about 80 percent.

This technology was accepted into the SITE Emerging Technology Program in July 1991. Laboratory studies have been underway since January 1991. Bench-scale tests have successfully met targets for removal of several heavy metal contaminants.

Arsenic and mercury have proved more difficult to remove; however, laboratory tests have reduced arsenic to below 30 milligrams per kilogram (mg/kg) in soil and mercury to 0.5 mg/kg in soil in the major fraction of the soil. A location to demonstrate a small pilot plant is being sought.

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and Environmental Division
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The SITE Program assesses but does not approve or endorse technologies.

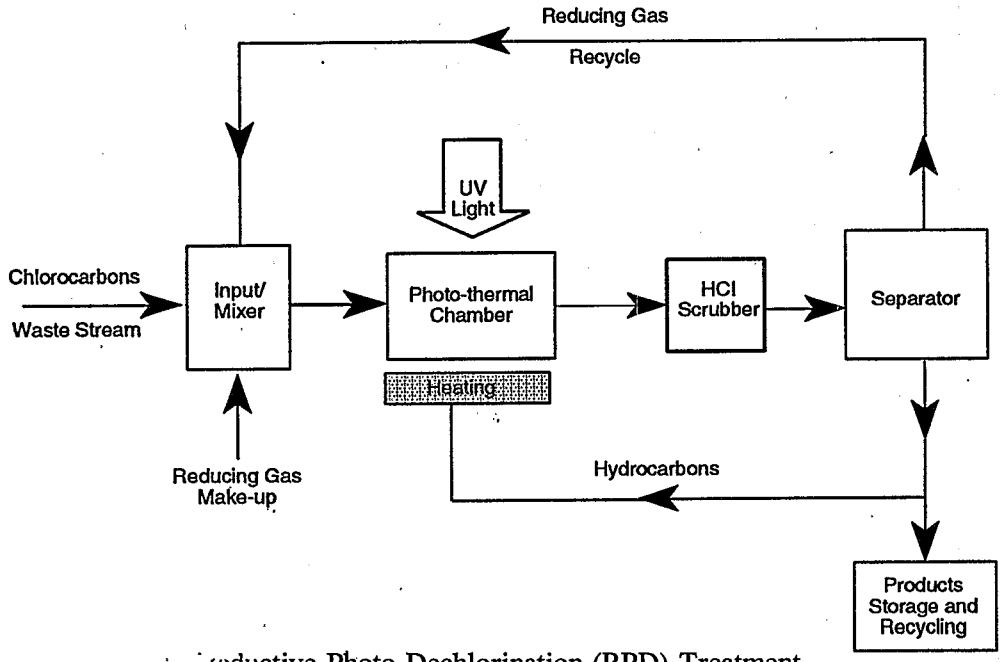
M. L. ENERGIA, INC.
(Reductive Photo-Dechlorination Treatment)

TECHNOLOGY DESCRIPTION:

The Reductive Photo-Dechlorination (RPD) treatment uses ultraviolet (UV) light in a reducing atmosphere and at moderate temperatures to treat waste streams containing chlorinated hydrocarbons (ClHC). Because ClHCs are destroyed in a reducing environment, the only products are hydrocarbons and hydrogen chloride (HCl).

The RPD process is schematically depicted in the figure below. The RPD process consists of five main units: 1) input/mixer; 2) photo-thermal chamber; 3) HCl scrubber; 4) separator; and 5) product storage and recycling. Chlorinated wastes may be introduced into the process in one of three ways: as a vapor, a liquid, or bound to an adsorbent, such as activated carbon. Air laden with chlorocarbon vapors is first passed through a separator, which removes chlorinated materials as a liquid. Chlorocarbon liquids are fed into a vaporizer, mixed with a reducing gas, and passed into the photo-thermal chamber. Chlorinated contaminants adsorbed onto activated carbon are purged with reducing gas and mildly heated to induce vaporization. The ensuing vapors are then fed into the photo-thermal chamber.

The photo-thermal chamber is the heart of the RPD process because all reactions central to the process occur in this chamber. Saturated, olefinic, or aromatic chlorocarbons with one or more carbon-chlorine bonds are exposed to UV light, heat, and a reducing atmosphere, such as hydrogen gas or methane (natural gas). Carbon-chlorine bonds are broken, resulting in chain-propagating hydrocarbon reactions. Chlorine atoms are eventually stabilized as HCl. Hydrocarbons may hold their original structures, rearrange, cleave, couple, or go through additional hydrogenation. Hydrocarbons produced from the dechlorination of wastes include ethane, acetylene, ethylene, and methane. Valuable hydrocarbon products are stored or sold. Optionally, the hydrocarbons may be recycled as auxiliary fuel to heat the photo-thermal chamber.



Reductive Photo-Dechlorination (RPD) Treatment

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The RPD process is designed specifically to treat volatile chlorinated wastes in the liquid or gaseous state. The RPD process was tested for trichlorethylene, trichloroethane (TCA), dichloroethylene, dichloroethane, vinyl chloride, ethyl chloride, dichloromethane, and chloroform. The process may also be applicable to tetrachloroethylene, carbon tetrachloride, and chlorinated aromatics, which will be tested under the Emerging Technology Program.

Field applications include treatment of organic wastes, discharged soil venting operations, and contaminants adsorbed on activated carbon. The process can be used for treatment of gas streams containing chlorinated hydrocarbons, and to pretreat gas streams entering catalytic oxidation systems, reducing chlorine content and protecting the catalyst against poisoning.

STATUS:

The RPD technology was accepted into the SITE Emerging Technology Program in summer 1992. Since then, the RPD technology has successfully completed the bench-scale developmental stage, from which a pilot-scale prototype unit is under construction. Experimental results on a representative chlorocarbon contaminant (for example, TCA) have demonstrated greater than 99 percent conversion and dechlorination, with high selectivity towards two valuable hydrocarbon products (C_2H_6 and CH_4). Similar favorable results have been obtained for other saturated and unsaturated chlorocarbons treated by the RPD process. Preliminary cost analysis shows that the process is extremely cost-competitive with other remedial processes; the estimated cost is less than $1 per pound of treated chloro-carbon. A SITE demonstration is scheduled, after which the RPD technology will be available for commercialization.

FOR FURTHER INFORMATION:

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Fax: 609-799-0312

The SITE Program assesses but does not approve or endorse technologies.

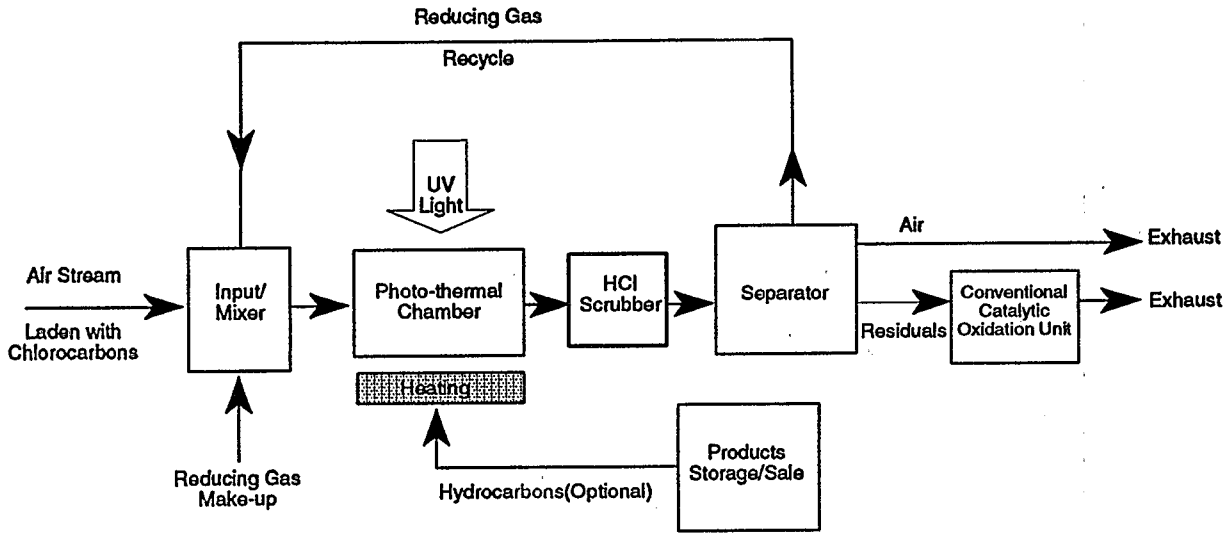
M.L. ENERGIA, INC.
(Reductive Thermal and Photo-Thermal Oxidation Processes for Enhanced Conversion of Chlorocarbons)

TECHNOLOGY DESCRIPTION:

Two innovative processes, Reductive Thermal Oxidation (RTO) and Reductive Photo-Thermal Oxidation (RPTO), safely and cost-effectively convert chlorinated hydrocarbons (ClHC) into environmentally benign and useful materials. Both processes treat air streams laden with ClHCs. RTO converts ClHCs at moderate temperatures by cleaving C-Cl bond in the absence of ultraviolet light. RPTO operates under similar conditions in the presence of ultra-violet light. Subsequent reactions between ensuing radicals and the reducing gas results in chain-propagation reactions. The presence of air (oxygen) during the conversion process accelerates the overall reaction rate without significant oxidation. The final products are useful hydrocarbons and environmentally-safe materials including hydrogen chloride, carbon dioxide, and water.

A schematic of the RTO/RPTO processes is shown in the figure below. The process consists of six main units: 1) input/mixer; 2) photo-thermal chamber; 3) scrubber; 4) separator; 5) storage/sale; and 6) conventional catalytic oxidation unit. Air laden with ClHCs is mixed with reducing gas and passed into a photo-thermal chamber, which is the heart of the RTO/RPTO technology. In this chamber, the mixture is heated to moderate temperatures to sustain the radical chain reactions. Depending on the physical/chemical characteristics of the particular ClHCs treated, conversion can take place in two ways: the RTO process is pure thermal, and the RPTO process is photo-thermal. After suitable residence time, HCl is removed by passing the stream through an aqueous scrubber. The stream can then be treated in an optional second storage, or separated and sent to storage.

Excess reducing gas is recycled, and residual (sub parts per million) ClHCs, HCs, and CO are treated by catalytic oxidation. Volatile hydrocarbons can also be recycled as an energy source for process heating, if partial oxidation at the



ENERGIA's Reductive Thermal Oxidation (RTO) and Photo-Thermal Oxidation (RPTO) Processes

The SITE Program assesses but does not approve or endorse technologies.

photo-thermal chamber does not generate enough heat.

WASTE APPLICABILITY:

This technology removes volatile hydrocarbons from air streams. Field applications include direct treatment (no air separation) of air streams contaminated with chlorocarbons, wastes discharged from soil vapor extraction or vented from industrial hoods and stacks, and those adsorbed on granular activated carbon. The process can also be applicable for in situ treatment of sites containing contaminated ground and surface waters.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1994. Laboratory-scale tests have been conducted on two representatives of saturated ClHCs (dichloromethane and trichloroethane), and on two representatives of unsaturated ClHCs (1,2-dichloroethylene and trichloroethylene). The RTO and RPTO processes have demonstrated 99 percent or more conversion/dechlorination with high selectivity towards valuable hydrocarbon products (CH_4 and C_2H_6).

FOR FURTHER INFORMATION:

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The SITE Program assesses but does not approve or endorse technologies.

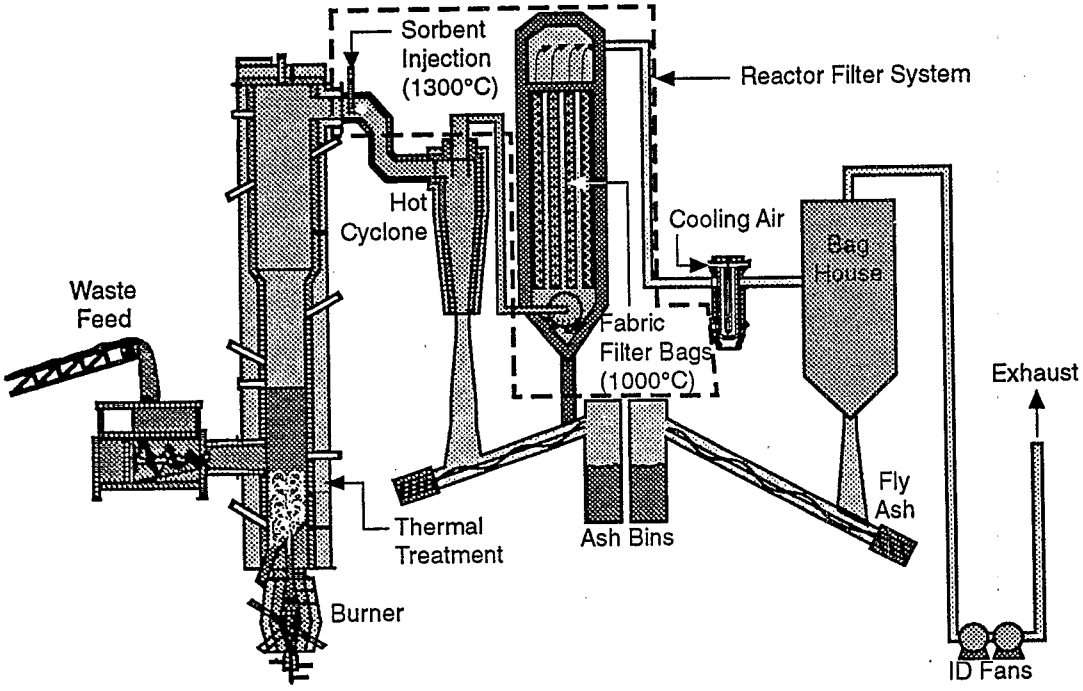
ENERGY AND ENVIRONMENTAL RESEARCH CORPORATION
(Reactor Filter System)

TECHNOLOGY DESCRIPTION:

The Reactor Filter System (RFS) technology controls gaseous and entrained particulate matter emissions generated from the primary thermal treatment of sludges, soils, and sediments. Most Superfund sites are contaminated with toxic organic chemicals and metals. Currently available thermal treatment systems for detoxifying these materials release products of incomplete combustion (PIC) and volatile toxic metals. Also, large air pollution control devices (APCD), often required to control PICs and metals, are generally not suited for transport to remote Superfund sites. Energy and Environmental Research Corporation (EER) is currently developing the RFS to avoid some of the logistical problems associated with conventional APCD.

The RFS uses a fabric filter immediately downstream of the thermal treatment process to control toxic metals, particulates, and unburned organic species. The RFS involves the following three steps:

- First, solids are treated with a primary thermal process, such as a rotary kiln, fluidized bed, or other system.
- Next, a low-cost, aluminosilicate sorbent such as kaolinite is injected into the flue gases at temperatures near 1,300 degrees Celsius (°C) (2,370 degrees Fahrenheit [°F]). The sorbent reacts with volatile metal species such as lead, cadmium, and arsenic in the gas stream and chemically adsorbs onto the surfaces of the sorbent particles. This reaction forms insoluble, nonleachable alumino-



Example Application of RFS Equipment

The SITE Program assesses but does not approve or endorse technologies.

silicate complexes similar to cementitious species.

- Finally, high-temperature fabric filtration up to 1,000 °C (1,830 °F) provides additional residence time for the sorbent/metal reaction to produce nonleachable by-products. This step also provides additional time for destruction of organic compounds in particulate matter, reducing ash toxicity. Because of the established link between PIC formation and gas-particle chemistry, this process can also virtually eliminate potential polychlorinated dioxin formation.

The RFS can dramatically improve the performance of existing thermal treatment systems for Superfund wastes that contain metals and organics. During incineration, hazardous organics are often attached to the particulate matter that escapes burning in the primary zone. The RFS provides sufficient residence time at sufficiently high temperatures to destroy such organics. Also, the system can decrease metal emissions by increasing gas-solid contact parameters, and preventing the release of metals as vapors or as retained material on entrained particles.

The figure on the previous page shows the RFS installed immediately downstream of the primary thermal treatment zone at EER's Spouted Bed Combustion Facility. Because the spouted bed generates a highly particulate-laden gas stream, a high temperature cyclone removes coarse particulate matter upstream of the RFS. Sorbent is injected into the flue gas upstream of the high temperature fabric filter. A conventional baghouse is available to compare RFS performance during the demonstration, but is not needed in typical RFS applications.

WASTE APPLICABILITY:

The RFS is designed to remove entrained particulates, volatile toxic metals, and condensed-phase organics generated by thermal treatment of contaminated soils, sludges, and sediments from high temperature (800 to 1,000 °C) gas streams. Many conventional treatments can be combined with the RFS technology. Process residuals consist of nonleachable particulate that is essentially free of organic compounds, thus reducing toxicity, handling risks, and landfill disposal.

STATUS:

The RFS was accepted into the Emerging Technology Program in 1993. The pilot-scale RFS will be designed and demonstrated during the two-year program. EER developed the pilot-scale process through a series of screening studies, completed in September 1994, which guided the sorbent selection and operating conditions for the pilot-scale demonstration. The pilot-scale RFS demonstration is scheduled for early 1995.

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The SITE Program assesses but does not approve or endorse technologies.

ENVIRONMENTAL BIOTECHNOLOGIES, INC.
(Microbial Composting Process)

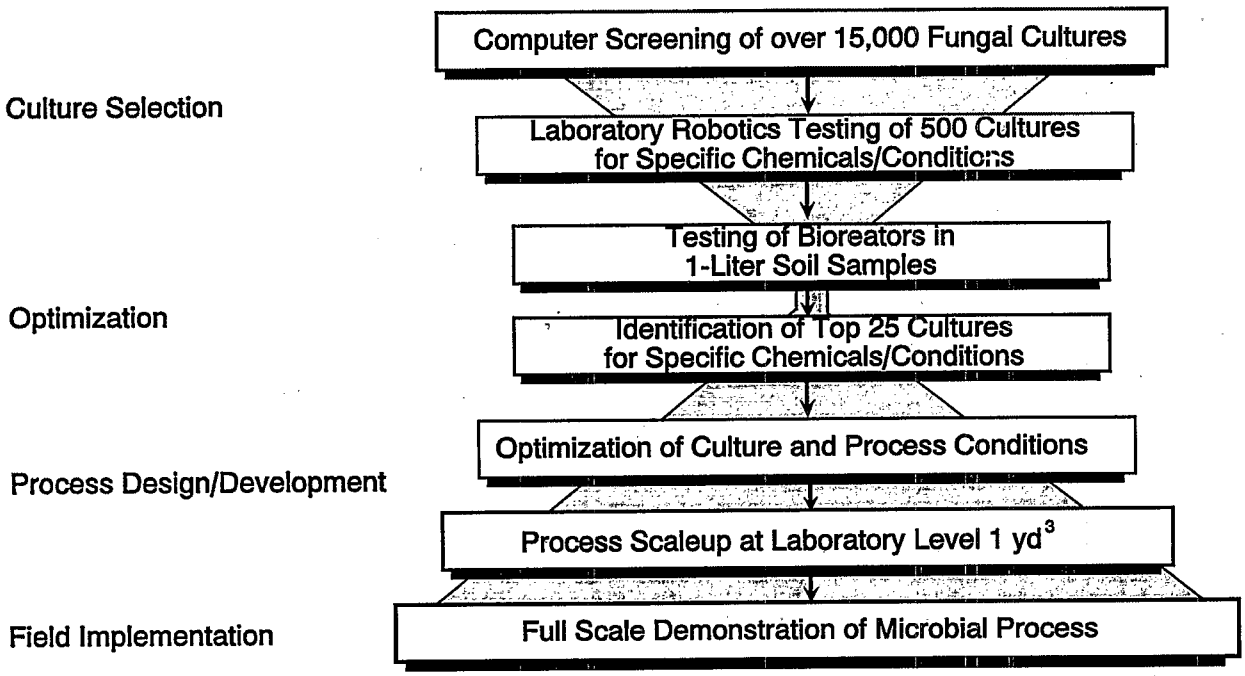
TECHNOLOGY DESCRIPTION:

Environmental BioTechnologies, Inc. (EBT), investigated the bioremediation of contaminants associated with former manufactured gas plant (MGP) sites in programs sponsored by the Electric Power Research Institute (EPRI). In EBT's program, initial screening of over 15,000 fungi of the Basidiomycetes class (mostly brown and white rot fungi) led to 500 cultures that were selected for a laboratory-automated screening program.

This program tested these diverse fungi for metabolic activity against a wide range of organic pollutants associated with the utilities industry. The program also examined the effects of environmental conditions (pH and nutrients) on fungal metabolic activities. Well-studied cultures such as *Phanerochaete chrysosporium* and *Coriolus versicolor* were used to determine which fungal cultures displayed potential for environmental applications.

Another EPRI contractor, Michigan Biotechnology Institute (MBI), developed a method to treat soils contaminated with polycyclic aromatic wastes from MGP sites. This method involves providing the proper environmental conditions to allow proliferation of fungi, which were selected based on their ability to degrade coal tar components. Selected cultures from the EBT screening program performed well in MBI's soil treatment bioreactors. This process is focused on treatment in prepared bed systems and in situ treatment.

Due to the wide variability in environmental conditions and the structure and partitioning of organic contaminants, no single microorganism exists that is applicable to every site. Therefore, EBT and MBI have developed a relatively rapid method to screen for a group of organisms with the desired traits and degradation capabilities. One or several appropriate organisms can then be selected for a development program. The



Pathway of Fungal Technology Development Program

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overall strategy involves culture screening and development along with process optimization and design, as shown in the figure on the previous page. As process development proceeds, fungal and bacterial consortia are evaluated and process conditions optimized to support the desired degradative function.

During the screening program, EBT identified top fungal cultures for polycyclic aromatic hydrocarbon (PAH) degradation. Selected cultures tested in bench-scale bioreactors indicated that fungi selected based on screening assays performed better than other well-studied fungi. PAH degradation significantly improved when three fungi were added to contaminated soil along with lignocellulosic co-substrates and humic-based fertilizer. However, more information is needed on factors such as optimal cultures for specific applications, aeration, mixing requirements, timing of microbial and nutrient augmentation, and bioavailability of hazardous compounds. These parameters will help develop fungal composting as a reliable method for degrading PAHs. Also, different types of soil may impact fungal activity.

WASTE APPLICABILITY:

This technology is being developed to treat soil and sediment contaminated with coal tar wastes (PAHs) from former MGP sites. The program results and technology will also be applicable to aqueous systems.

STATUS:

EBT was accepted into the SITE Emerging Technology Program in 1993, and started laboratory studies in 1994. The overall objectives of testing under this program are to 1) identify fungal and bacterial cultures capable of efficiently degrading coal tar wastes, and 2) develop and demonstrate a pilot-scale process that can be commercialized for utility industry applications.

EBT will initially work with PAH-spiked water and soils. EBT will then test selected soil cultures from several MGP sites under optimized conditions, as identified by New England Electric Services, a utility company sponsor. Current testing has identified several possibly superior fungal cultures to degrade PAHs. Cultures identified exhibited degradative preferences for either lower molecular-weight or higher molecular-weight PAHs, suggesting a consortia as a possible best approach. These cultures are now being examined in nutrient-supplemented systems to determine optimal PAH degradation rates.

A bench-scale composter system will determine optimal moisture content, soil amendment requirements, and inoculation procedures for accelerating degradation of PAHs in these coal tar-contaminated soils. In the second year, small (less than one cubic yard) plots of MGP-site soil will test the optimized process in laboratory studies before a field demonstration is conducted.

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The SITE Program assesses but does not approve or endorse technologies.

GENERAL ATOMICS, NUCLEAR REMEDIATION TECHNOLOGIES DIVISION
(Acoustic Barrier Particulate Separator)

TECHNOLOGY DESCRIPTION:

The acoustic barrier particulate separator separates particulates in a high temperature gas flow. The separator produces an acoustic waveform directed against the gas flow, causing particulates to move opposite the flow. Eventually, the particulates drift to the wall of the separator, where they aggregate with other particulates and precipitate into a collection hopper. The acoustic barrier separator differs from other separators by combining both high efficiency and high temperature capabilities.

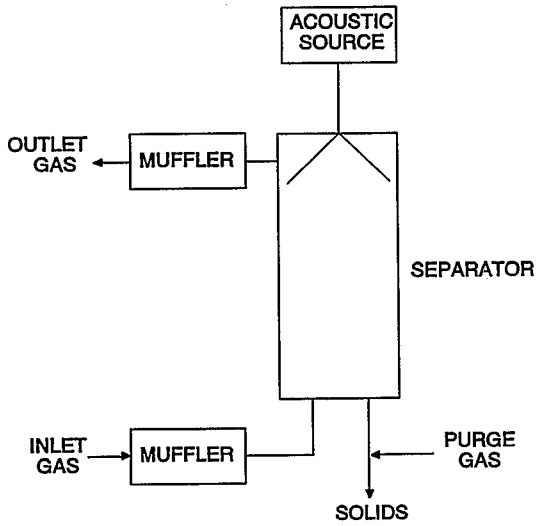
The figure below presents a conceptual design. High temperature gas flows through a muffler chamber and an agglomeration segment before entering the separation chamber. In the separation chamber, particulates stagnate due to the acoustic force and drift to the chamber wall, where they collect as a dust cake that falls into a collection hopper. The solids are transported from the collection hopper against a clean purge gas counterflow. The purge gas cools the solids as the gas is heated and guards against contamination of particulates by volatiles in the process stream. A screw-type conveyor helps transport the solids.

The gas flows past an acoustic horn and leaves the chamber through an exit port. The gas then passes through another muffler chamber and flows through sections where it is cooled and gas-borne particulate samples are collected. Finally, the gas is further scrubbed or filtered as necessary before it is discharged.

The separator can remove the entire range of particle sizes; it has a removal efficiency of greater than 90 percent for submicron particles and an overall removal efficiency of greater than 99 percent. Due to the large diameter of the separator, the system is not prone to fouling.

WASTE APPLICABILITY:

This technology can treat off-gas streams from thermal desorption, pyrolysis, and incineration of soil, sediment, sludges, other solid wastes, and liquid wastes. The acoustic barrier partic-



Schematic Diagram of the Acoustic Barrier Particulate Separator

The SITE Program assesses but does not approve or endorse technologies.

ulate separator is a high temperature, high throughput process with a high removal efficiency for fine dust and fly ash. The acoustic barrier separator is particularly suited for thermal processes where high temperatures must be maintained to prevent condensation onto particulates. Applications include removal of gas-borne solids during thermal treatment of semivolatile organics, such as polychlorinated biphenyls, and gas-phase separation of radioactive particles from condensible hazardous materials.

STATUS:

The acoustic barrier particulate separator was accepted into the SITE Emerging Technology Program in 1993. The principal objective of this project will be to design, construct, and test a pilot-scale acoustic barrier separator that is suitable for parallel arrangement into larger systems. The separator will be designed for a flow of 300 cubic feet per minute and will be tested using a simulated flue gas composed of heated gas and injected dust.

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The SITE Program assesses but does not approve or endorse technologies.

GEO-MICROBIAL TECHNOLOGIES, INC.
(Metals Release and Removal from Wastes)

TECHNOLOGY DESCRIPTION:

A novel anaerobic biotreatment technology has been developed by Geo-Microbial Technologies, Inc., to release metals from spent coal liquefaction catalyst wastes that are also contaminated with complex organic compounds. This new biotreatment technology may be adapted to treat other wastes that are contaminated by toxic metals. The objective of this project is to demonstrate the capabilities of this anaerobic process to release toxic metal from contaminated soil.

Biological treatment diversity offers the opportunity to select the biological system that is most effective for the targeted pollutant. This technology targets wastes including toxic metal-contaminated soils, sludges, and sediments contaminated with other wastes, including hydrocarbons and organic pollutants. While metals are the primary pollutant that will be treated, the biological system is also designed to degrade and remove associated organic contaminants.

Current prominent biohydrometallurgy systems use aerobic acidophilic bacteria, which are capable of oxidizing mineral sulfides while solubilizing metals and forming copious amounts of acid. This aerobic process can lead to the production of acidic drainage from natural sources of metal sulfides. For example, acidophilic bacteria convert the pyrite and iron-containing minerals in coal into oxidized iron and sulfuric acid. The acid then further solubilizes the pyrite and other sulfide minerals. The result is contamination of streams and lakes due to acidification and an increase in soluble heavy metals.

Geo-Microbial Technologies, Inc., has discovered and developed a new and different approach to release and remove toxic metals. This system operates anaerobically and at a near neutral pH, employing anaerobic *Thiobacillus* cultures in consortium with heterotrophic denitrifying cultures. Controlled manipulations of the anaerobic environment by addition of simple alternate electron acceptor nutrients stimulates the denitrifying microbial populations. The diversity of the ubiquitous denitrifers allows multiple carbon sources, including some organic pollutants, to be utilized and treated. The elimination of the requirements for oxygen and aerobic conditions offers the potential for in situ, heap leaching, and bioslurry operations. A greater range of treatment applications is offered for environmental waste situations that previously were considered difficult to treat. The biotreatment action releases no acid or toxic gases, thus offering an environmentally benign process.

WASTE APPLICABILITY:

This technology treats soils, sludges, and sediments contaminated with metals, hydrocarbons, and organic pollutants.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1994.

The SITE Program assesses but does not approve or endorse technologies.

FOR FURTHER INFORMATION:

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The SITE Program assesses but does not approve or endorse technologies.

GROUNDWATER TECHNOLOGY GOVERNMENT SERVICES, INC.

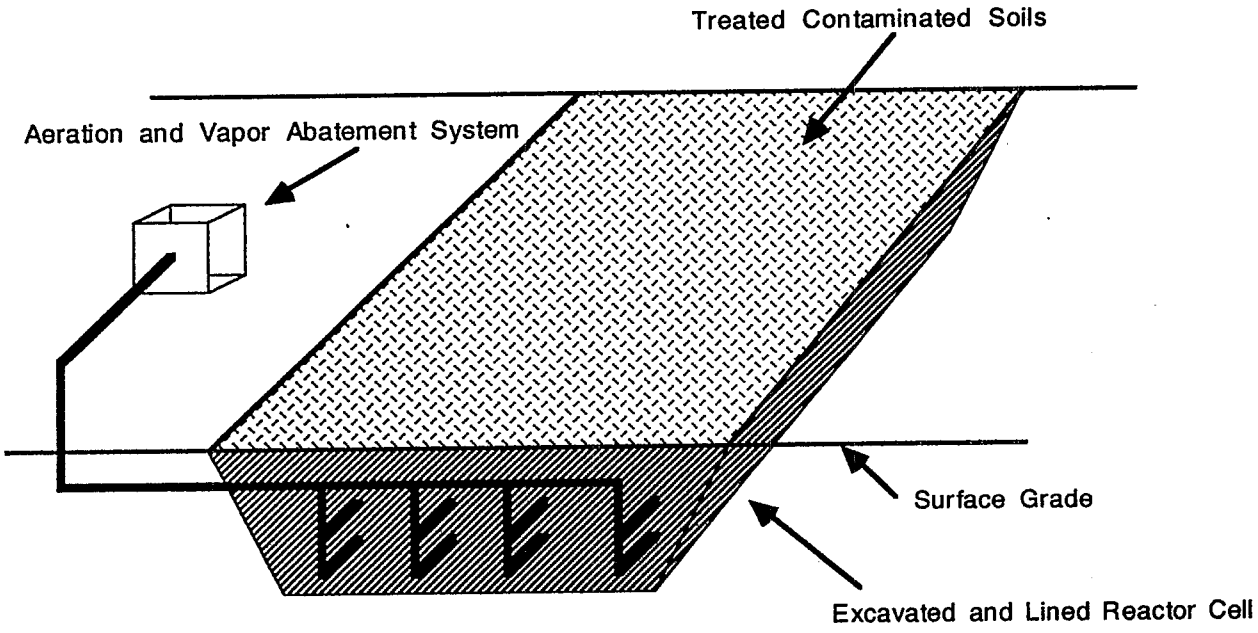
(Below-Grade Bioremediation of Chlorinated Cyclodiene Insecticides)

TECHNOLOGY DESCRIPTION:

This technology adds strains of naturally-occurring fungus to pesticide-contaminated soil, which is then treated in a below-grade active aeration bioremediation cell.

Cyclodiene insecticides, such as chlordane and heptachlor, have been applied for years to protect wood frame structures against termites. This compound group is one of the top 50 most frequently found contaminants at Superfund sites. Because of the high stability in soils, low aqueous solubility and relatively low volatility of this compound group, there is a great need to develop effective and cost-efficient remediation technologies. Several species of lignin-degrading fungi degrade recalcitrant organic contaminants, including chlorinated aromatic hydrocarbons, under select conditions. Apparently, these fungi generate enzymes that metabolize naturally occurring complex polymers such as lignin. This study will examine the ability of certain fungal strains to metabolize chlordane and heptachlor in a soil matrix.

Phase I of the study was designed to select a fungal strain which demonstrated the best performance in laboratory microcosm tests. A comparative evaluation of three lignin-degrading fungi was performed in soil microcosm experiments using *Phanerochaete chrysosporium*, *Trametes versicolor*, or *Bjerckendera adusta*. During Phase II, the chemical and physical conditions required for optimum growth and degradation will be determined for the selected strain. In Phase III, a small pilot-scale treatment system will be tested, using the fungal strain applied to a simulated below-grade bioremediation cell, with the goal of demonstrating the effectiveness of fungal bioremediation under



Below-Grade Bioremediation Cell

The SITE Program assesses but does not approve or endorse technologies.

field conditions. The figure on the previous page illustrates the technology.

WASTE APPLICABILITY:

Applicable waste media include soil, sludge, and sediment impacted with chlordane and/or heptachlor. Technical-grade chlordane is actually a mixture of over 20 chemicals, including heptachlor. This study will examine the treatability of the predominant individual constituents as well as the mixture taken as a whole, since it is in this form that the environmental contamination is most often found. Because of the sensitivity of certain fungal strains to chemical and physical conditions, properties of the particular waste matrix are expected to have a significant influence on the technology's effectiveness.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in summer 1991. Results of Phase I tests demonstrated greater than 87 percent removal of heptachlor and 70 percent removal of *trans*-chlordane after 90 days of treatment. Removal efficiencies of 40 to 60 percent were observed for *cis*-chlordane. Reductions in control microcosms amended with sterilized inoculum and subjected to the same aeration schedule were 30 percent for the chlordane isomers and 50 percent for heptachlor. *T. versicolor* removed the greatest amount of the two chlordane isomers and total chlordane constituents, while *P. chrysosporium* removed the greatest amount of heptachlor.

Additional observations were made regarding differences in macroscopic growth characteristics and growth durability between fungal strains once inoculated to soil. These traits may have important implications with respect to full-scale soil treatment. *P. chrysosporium* grew primarily in concentrated areas within the soil mass. *B. adusta* was well-distributed throughout the soil surface, with some penetration into the depths of the soil mass. The growth pattern of *T. versicolor* was intermediate between the two extremes, with some growth occurring in discrete areas and some diffusion and connection between these areas. Differences in growth persistence between fungal strains were also observed, with *P. chrysosporium* and *T. versicolor* showing much greater persistence than *B. adusta* when provided with regular additions of carbon and mineral nutrients. Based on these observations and the degradation data, *T. versicolor* was selected for use in subsequent optimization and pilot-scale experimentation.

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The SITE Program assesses but does not approve or endorse technologies.

HIGH VOLTAGE ENVIRONMENTAL APPLICATIONS, INC.
(High Energy Electron Beam Irradiation)

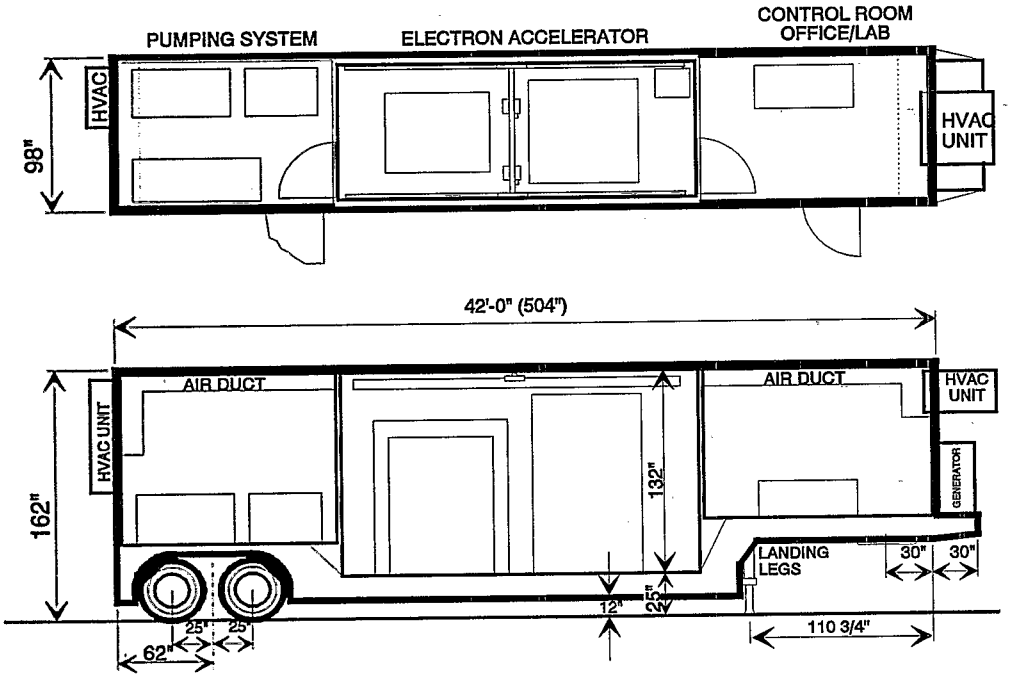
TECHNOLOGY DESCRIPTION:

The high energy electron beam irradiation technology is a low temperature method for destroying complex mixtures of hazardous organic chemicals in solutions containing solids. These solutions include slurried soils, river or harbor sediments, and sludges. The technology can also treat contaminated soils and groundwater.

The figure below illustrates the mobile electron beam treatment system. The system consists of a computer-automated, portable electron beam accelerator and a delivery system. The 500-kilovolt electron accelerator produces a continuously variable beam current from 0 to 40 milliamperes. At full power, the system is rated at 20 kilowatts. The flow rate can be adjusted up to 50 gallons per minute. The flow rate and beam current can be varied to obtain doses of up to 2,000 kilorads in a one-pass, flow-through mode.

The system is trailer-mounted and is completely self-contained, including a 100 kilowatt generator for remote locations or line connectors where power is available. The system requires only a mixing tank to slurry the treatable solids. The system also includes all necessary safety checks.

The computerized control system continuously monitors the flow rate, absorbed dose, accelerator potential, beam current, and all safety shutdown features. The flow rate is monitored with a calibrated flow valve. The absorbed dose is estimated based on the difference in the temperature of the waste stream before and after irradiation. The system is



Mobile Electron Beam Hazardous Waste Treatment System

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equipped with monitoring devices that measure the waste stream temperature before and after irradiation. Both the accelerating potential and the beam current are obtained directly from the transformer. Except for slurrying, this technology does not require pretreatment of wastes.

WASTE APPLICABILITY:

This technology treats a variety of organic compounds, including wood treating chemicals, pesticides, insecticides, petroleum residues, and polychlorinated biphenyls (PCB) in slurried soils, sediments, and sludges.

STATUS:

High Voltage Environment Applications, Inc. (HVEA), was accepted into the SITE Emerging Technology Program in 1993. Under this program, HVEA will demonstrate its mobile pilot plant on soils, sediments or sludges at various hazardous waste sites. Candidate sites are being identified. On-site studies will last up to 2 months.

Initial studies by HVEA have shown that electron beam irradiation removes greater than 99 percent of trichloroethene, tetrachloroethene, chloroform, benzene, toluene, and phenol in aqueous streams. HVEA has also demonstrated effective removal of 2,4,6-trinitrotoluene from soil slurries.

In a recent bench-scale study, a multisource hazardous waste leachate containing 1 percent dense nonaqueous phase liquid was successfully treated. In another bench-scale study, a leachate containing a light nonaqueous phase liquid contaminated with PCBs was treated to F039 standards.

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The SITE Program assesses but does not approve or endorse technologies.

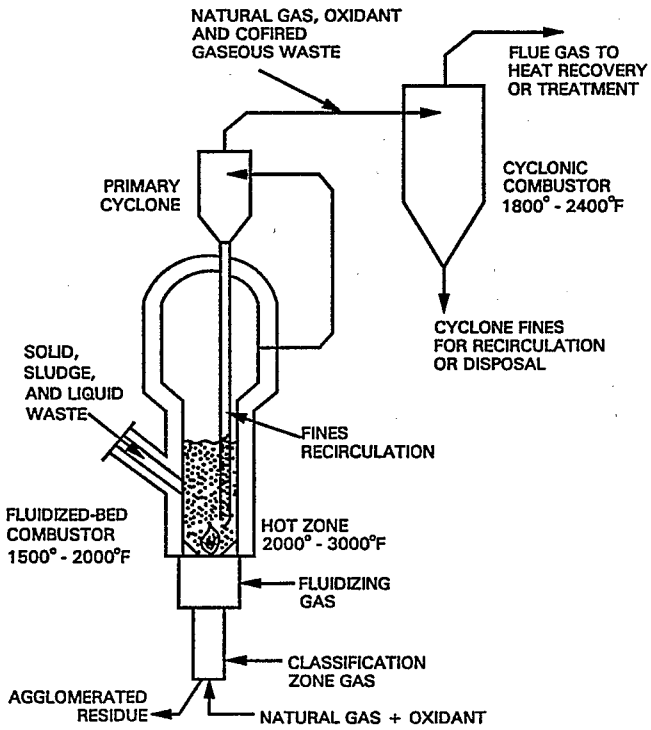
INSTITUTE OF GAS TECHNOLOGY
(Fluidized-Bed Cyclonic Agglomerating Combustor)

TECHNOLOGY DESCRIPTION:

The Institute of Gas Technology (IGT) has developed a two-stage, fluidized-bed cyclonic agglomerating combustor based on a combination of IGT technologies (see figure below). In the combined system, solid, liquid, and gaseous organic wastes can be efficiently destroyed. Solid, nonvolatile, inorganic contaminants are combined within a glassy matrix consisting of discrete pebble-sized agglomerates that are suitable for disposal in a landfill.

The first stage of the combustor is an agglomerating fluidized-bed reactor, which can operate under substoichiometric conditions or with excess air. This system can operate from low temperature (desorption) to high temperature (agglomeration). This system can also gasify materials with high calorific values (for example, municipal solid wastes). With a unique fuel and air distribution, most of the fluidized bed is maintained at 1,500 to 2,000 degrees Fahrenheit (°F), while the central spout temperature can be varied between 2,000 and 3,000 °F.

When contaminated soils and sludges are fed into the fluidized bed, the combustible fraction of the waste is rapidly gasified and combusted. The solid fraction, containing inorganic and metallic contaminants, undergoes a chemical transformation in the hot zone and is agglomerated into glassy pellets. These pellets are essentially nonleachable under the conditions of the toxicity characteristic leaching procedure (TCLP). The product gas from the fluidized bed may contain unburned hydrocarbons, furans, dioxins, and carbon monoxide as well as carbon



Two-Stage Fluidized-Bed/Cyclonic Agglomerating Combustor

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dioxide and water, the products of complete combustion.

The product gas from the fluidized bed is fed into the second stage of the combustor, where it is further combusted at a temperature of 1,800 to 2,400 °F. The second stage is a cyclonic combustor and separator that provides sufficient residence time (0.25 seconds) to oxidize carbon monoxide and organic compounds to carbon dioxide and water vapor. This stage has a combined destruction and removal efficiency greater than 99.99 percent. Volatilized metals are collected downstream in the flue gas scrubber condensate.

The two-stage fluidized-bed cyclonic agglomerating combustor is based on IGT's experience with other fluidized-bed and cyclonic combustion systems. The patented sloping-grid design and ash discharge port in this process were initially developed for IGT's U-GAS coal gasification process. The cyclonic combustor and separator is a modification of IGT's low emissions combustor.

WASTE APPLICABILITY:

This two-stage combustor can destroy organic contaminants in gaseous, liquid, and solid wastes, including soils and sludges. Gaseous wastes can be fired directly into the cyclonic combustor. Liquid, sludge, and solid wastes can be co-fired directly into the fluidized bed. The solids particle size must be less than about 6 millimeters to support fluidized bed operation; therefore, certain wastes may require grinding or pulverization prior to remediation.

Because the solid components in the waste are heated above fusion temperature during the agglomeration process, metals and other inorganic materials are encapsulated and immobilized within the glassy matrix.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1990. Since then, tests conducted in the batch 6-inch diameter fluidized-bed unit have demonstrated that agglomerates can be formed from the soil. The agglomerates, produced at several different operating conditions, exhibit low leachability; however, the TCLP test results were inconclusive.

A pilot-plant combustor with a capacity of 6 tons per day has been constructed and testing is underway. Initial pilot plant tests have produced samples of agglomerated soil. The focus of future testing will be the sustained and continuous operation of the pilot plant. Tests with organic and inorganic hazardous waste surrogates admixed with the feed soil will also be conducted.

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The SITE Program assesses but does not approve or endorse technologies.

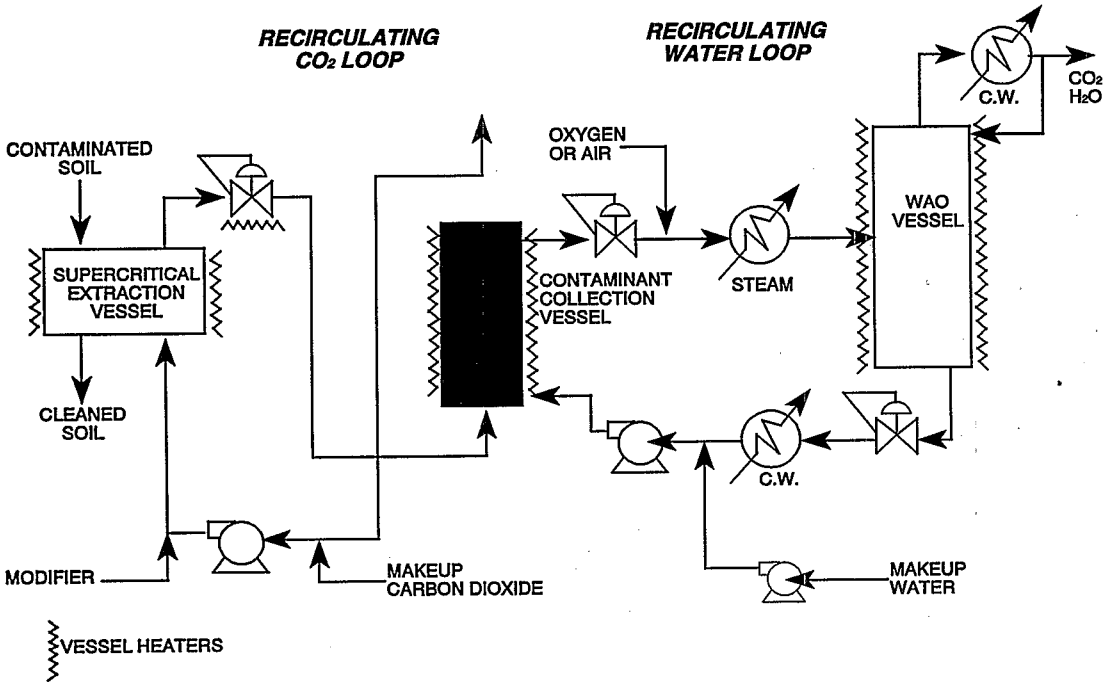
INSTITUTE OF GAS TECHNOLOGY
(Supercritical Extraction/Liquid Phase Oxidation)

TECHNOLOGY DESCRIPTION:

The Institute of Gas Technology's (IGT) Supercritical Extraction/Liquid Phase Oxidation (SELPhOx) process removes organic contaminants from soils and sludges and destroys them. SELPhOx combines two processing steps: 1) supercritical fluid extraction (SCE) of organic contaminants, and 2) wet air oxidation (WAO) destruction of the contaminants. The two-step process, linked by a phase separation stage, offers great flexibility for removing and destroying both high and low concentrations of organic contaminants.

IGT's primary objectives are to 1) evaluate SCE's contaminant removal efficiency, 2) determine the potential for carbon dioxide (CO_2) recovery and reuse, and 3) determine destruction efficiencies of extracted contaminants in the WAO process. Analytical results from the project will provide the necessary information for the full-scale process design.

Combining SCE and WAO in a single two-step process allows development of a highly efficient and economical process for remediating contaminated soils. Supercritical extraction with CO_2 can remove organic contaminants and leave much of the original soil organic matrix in place. The contaminants can then be collected and transported in an aqueous stream and fed to a WAO reactor for destruction. Concentrating the organic contaminants in water provides the proper matrix for a WAO feed stream, and improves process economics by decreasing the WAO reactor's size.



IGT's Supercritical Extraction/Liquid Phase Oxidation (SELPhOx) Process

The SITE Program assesses but does not approve or endorse technologies.

The SELPhOx process requires only water, air, and the extractant (CO_2). Primary treatment products include cleaned soil, water, nitrogen (from the air fed to the WAO step), and CO_2. Organic sulfur, nitrogen, and chloride compounds that may be present in the original soil or sludge matrix are transformed to relatively innocuous compounds in the product water. These compounds include sulfuric acid and hydrogen chloride, or their salts. The treated soil can be returned to the original site, and the water can be safely discharged after thermal energy recovery and minor secondary treatment. The gas can be depressurized by a turbo expander for energy recovery and then vented through a filter.

WASTE APPLICABILITY:

The SELPhOx process removes organic contaminants from soils and sludges, including chlorinated and nonchlorinated polynuclear aromatic hydrocarbons, polychlorinated biphenyls, and other organic contaminants.

STATUS:

The SELPhOx process was accepted into the SITE Emerging Technology Program in July 1994.

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The SITE Program assesses but does not approve or endorse technologies.

IT CORPORATION
(Chelation/Electrodeposition of Toxic Metals from Soils)

TECHNOLOGY DESCRIPTION:

IT Corporation has conducted laboratory-scale research on an innovative process that removes heavy metals from contaminated soils and sludges by forming a soluble chelate. The metal and chelating compound are then separated from the soils and recovered.

Soils are screened before the chelation step to remove large particles such as wood, metal scrap, and large rocks. The treatment employs two key steps: 1) using a water soluble chelating agent, such as ethylene-diaminetetra-acetic acid, to bond with heavy metals and form a chelate; and 2) recovering the heavy metals from the chelate and regenerating the chelating agent in an electromembrane reactor (EMR).

Dewatering is performed to separate the water soluble chelate that contains heavy metals from the solid phase. The resulting liquid is treated in an EMR, consisting of an electrolytic cell with a cation transfer membrane separating the cathode and anode chambers (see figure below). This demonstration will establish appropriate conditions for removal of specific metals from various types of hazardous wastes.

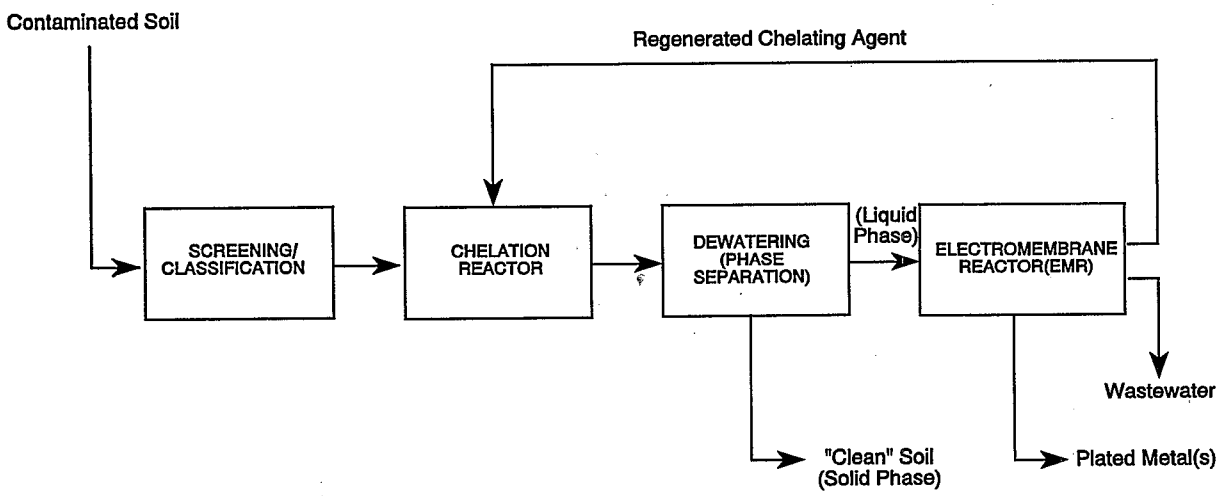
Previous research has focused primarily on the technology's applicability for treating and removing lead from contaminated soils and sludges. Limited work has also been conducted to determine the applicability for removing cadmium from soils and sludges.

WASTE APPLICABILITY:

The technology is potentially applicable for treating a wide variety of metal-contaminated hazardous wastes, including soils and sludges.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1994.



Simplified Process Flow Diagram of Overall Proposed Treatment Process

The SITE Program assesses but does not approve or endorse technologies.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
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The SITE Program assesses but does not approve or endorse technologies.

IT CORPORATION
(Eimco Biolift™ Slurry Reactor)

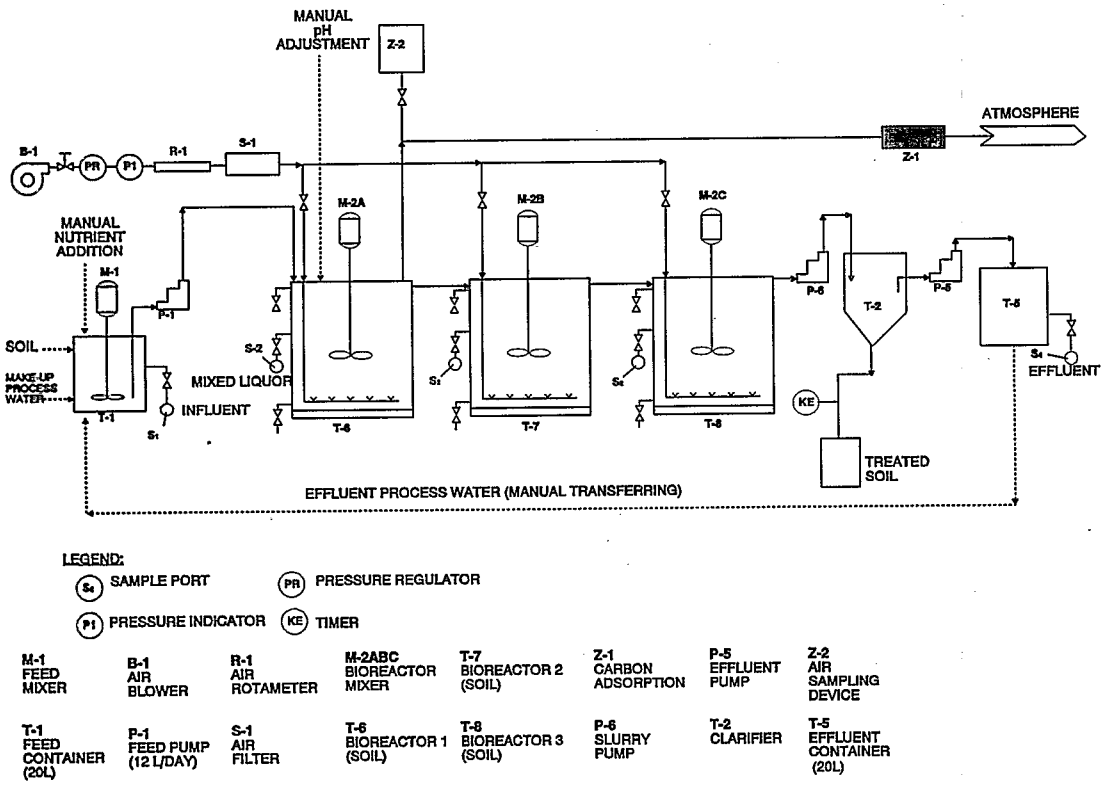
TECHNOLOGY DESCRIPTION:

IT Corporation (IT) has used the Eimco Biolift™ Slurry Reactor (developed by Eimco Process Equipment Company, Salt Lake City, Utah) to successfully treat polynuclear aromatic hydrocarbons (PAH) in soil. Traditional biological treatments, such as landfarming and in situ bioremediation, may not reduce PAHs in soil to target levels in a timely manner. Slurry reactors are more efficient for bioremediation and more economical than thermal desorption and incineration.

During the project, IT will operate two 60-liter Eimco Biolift™ reactors (see figure below) and a 10-liter fermentation unit in semicontinuous, plug-flow mode. The first 60-liter reactor will receive fresh feed daily and supplements of salicylate and succinate.

Salicylate induces the naphthalene degradation operon on PAH plasmids. This system has been shown to degrade phenanthrene and anthracene. The naphthalene pathway may also play a role in carcinogenic PAH (CPAH) metabolism.

Succinate is a by-product of naphthalene metabolism and serves as a general carbon source. The first reactor in series will remove easily degradable carbon and increase biological activity against more recalcitrant PAHs (i.e., three-ring compounds and higher).



Eimco Biolift™ Slurry Reactor System

The SITE Program assesses but does not approve or endorse technologies.

Effluent from the first reactor will overflow to the second 10-liter reactor in series, where Fenton's reagent will be added to accelerate oxidation for four- to six-ring PAHs. Fenton's reagent (hydrogen peroxide in the presence of iron salts) produces a free radical that can effectively oxidize multi-ring aromatic hydrocarbons.

The third 60-liter reactor in series will be used as a polishing reactor to remove any partially-oxidized contaminants remaining after Fenton's reagent is added. Slurry will be removed from this reactor and clarified using gravity settling techniques.

Operation of the reactors as described will increase the rate and extent of PAH biodegradation, making bioslurry treatment of impacted soils and sludges a more effective and economically attractive remediation option.

WASTE APPLICABILITY:

This technology is applicable to PAH-contaminated soils and sludges that can be readily excavated for slurry reactor treatment. Soils from coal gasification sites, wood treating facilities, petrochemical facilities, and coke plants are typically contaminated with PAHs.

STATUS:

IT's slurry reactor system was accepted into the SITE Emerging Technology Program in 1993. Under this program, IT will conduct a pilot-scale investigation of three slurry reactors operated in series. A suitable soil will be obtained and screened on site during summer 1994. The primary objective of the investigation is to achieve CPAH removal greater than 80 percent.

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The SITE Program assesses but does not approve or endorse technologies.

IT CORPORATION
(Mixed Waste Treatment Process)

TECHNOLOGY DESCRIPTION:

The mixed waste treatment process treats soils contaminated with hazardous and radioactive constituents. The process separates these contaminants into distinct organic and inorganic phases. The separated streams can then be further minimized, recycled, or destroyed at commercial disposal facilities, and the decontaminated soil can be returned to the site.

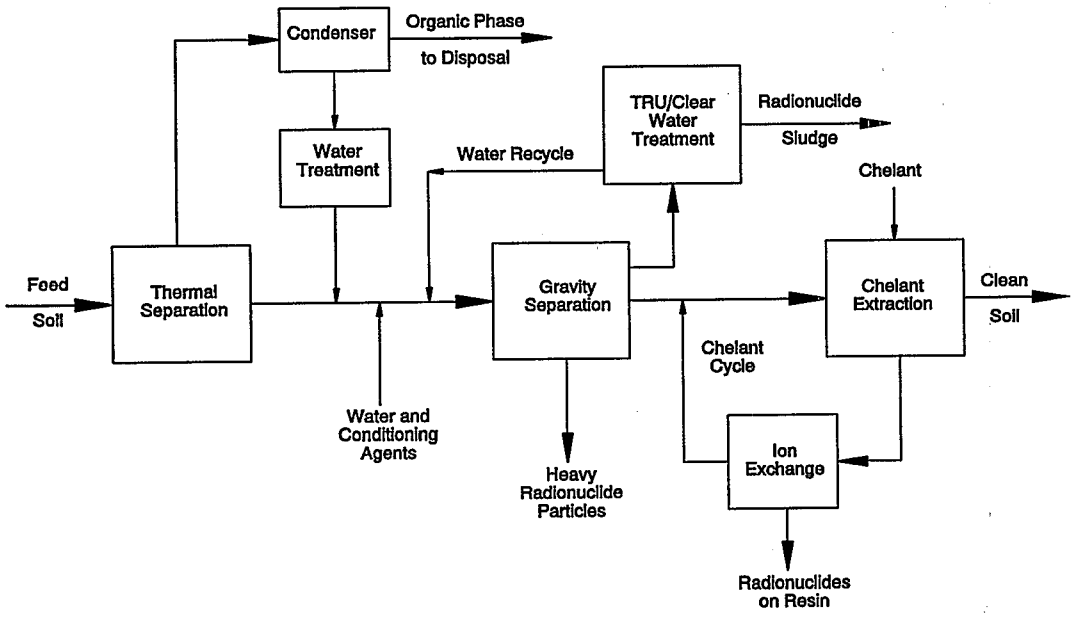
This process integrates thermal desorption, gravity separation, water treatment, and chelant extraction technologies. Each of these technologies has been individually demonstrated on selected contaminated materials. The process flow diagram below shows how the technologies have been integrated to treat mixed waste streams.

During the initial treatment step, feed is prepared with standard techniques and bulk contaminated soil is processed by crushing and grinding oversized material.

Thermal treatment removes volatile and semi-volatile organics from the soil. Soil is indirectly heated in a rotating chamber, volatilizing the organic contaminants and any moisture in the soil. The soil passes through the chamber and is collected as a dry solid. The volatilized organics and water are condensed into separate liquid phases. The organic phase is decanted and removed for disposal. The contaminated aqueous phase is passed through activated carbon, which removes soluble organics before combining with the thermally treated soil.

Inorganic contaminants are removed by three physical and chemical separation techniques: 1) gravity separation of high density particles; 2) chemical precipitation of soluble metals; and 3) chelant extraction of chemically bound metals.

Gravity separation is used to separate higher density particles from common soil. Radionuclide contaminants are typically found in this



Mixed Waste Treatment Process

The SITE Program assesses but does not approve or endorse technologies.

fraction. The gravity separation device (shaker table, jig, cone, or spiral) depends on contaminant distribution and the thermally treated soil's physical properties.

Many radionuclides and other heavy metals are dissolved or suspended in the aqueous separation media. These contaminants are separated from the soils and are precipitated. A potassium ferrate formulation precipitates radionuclides. The resulting microcrystalline precipitant is removed, allowing the aqueous stream to be recycled.

Some insoluble radionuclides remain with the soil through the gravity separation process. These radionuclides are removed by chelant extraction. The chelant solution then passes through an ion exchange resin to remove the radionuclides and is recycled to the soil extraction step.

The contaminants are collected as concentrates from all waste process streams for recovery or off-site disposal at commercial hazardous waste or radiological waste facilities. The decontaminated soil is then returned to the site as clean fill.

WASTE APPLICABILITY:

This process treats soils contaminated with organic, inorganic, and radioactive material.

STATUS:

The mixed waste treatment process was selected for the SITE Emerging Technology Program in October 1991. Bench- and pilot-scale testing is planned for late 1994. Individual components of the treatment process have been demonstrated on various wastes from U.S. Department of Energy (DOE), U.S. Department of Defense, and commercial sites. Thermal separation has removed and recovered PCBs from soils contaminated with uranium and technetium. These soils were from two separate DOE gaseous diffusion plants.

Gravity separation of radionuclides has been demonstrated at the pilot scale on Johnston Atoll, Guam. Gravity separation successfully removed plutonium from native coral soils.

Water treatment using the potassium ferrate formulations has been demonstrated at several DOE facilities in laboratory and full-scale tests. This treatment reduced cadmium, copper, lead, nickel, plutonium, silver, uranium, and zinc to dischargeable levels.

Chelant extraction has successfully treated surface contamination in the nuclear industry for more than 20 years. Similar results are expected for subsurface contamination.

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The SITE Program assesses but does not approve or endorse technologies.

LEWIS ENVIRONMENTAL SERVICES, INC./ HICKSON CORPORATION

(Chromated Copper Arsenate Soil Leaching Process)

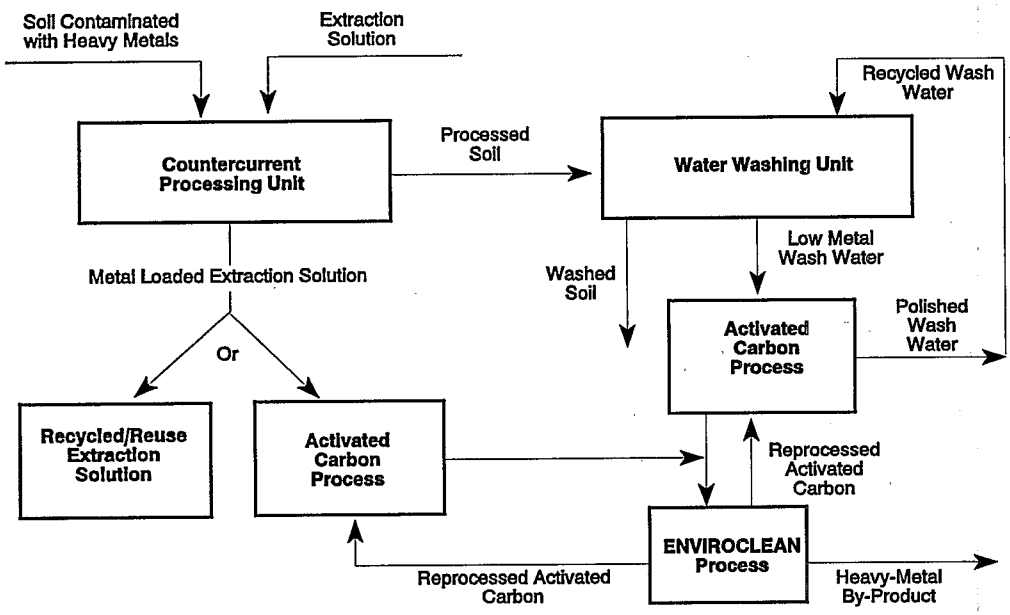
TECHNOLOGY DESCRIPTION:

Lewis Environmental Services, Inc. (Lewis), has developed a soil leaching process to remediate soils contaminated with heavy metals including chromium, copper, cadmium, mercury, arsenic, and lead. This process can treat soils contaminated with inorganics, some organics, heavy metal hydroxide sludges, and sediments.

The soil leaching process consists of leaching contaminated soil in a countercurrent stirred reactor system (see figure below). A screw feeder delivers the soil into the reactor, where it is leached with sulfuric acid for 30 to 60 minutes. The sulfuric acid solubilizes the inorganics and heavy metals into the leaching solution. The processed soil is then separated and washed with water and air-dried. Any organic contaminants are separated and decanted from the leaching acid, using strong acid leachate, space separation, and skimming.

The wash water is then treated with Lewis' ENVIRO-CLEAN process, which consists of a granulated activated carbon system followed by an electrolytic recovery system. The ENVIRO-CLEAN process recovers the heavy metals from the leaching stream and wash water and produces an effluent that meets EPA discharge limits for heavy metals. The treated wash water can then be reused in the soil washing step. The leaching solution can also be treated by the ENVIRO-CLEAN process or can be returned directly to the stirred reactor system, depending on its metals concentration.

Contaminated soil must be properly sized and screened to facilitate leaching in the stirred reactor system. Large pieces of debris such as rocks, wood, and bricks must be removed before treatment. Standard screening and classification equipment, such as that used in municipal waste treatment plants, is suitable for this purpose.



Chromated Copper Arsenate Soil Leaching Process

The SITE Program assesses but does not approve or endorse technologies.

The soil leaching process does not generate appreciable quantities of treatment by-products or waste streams containing heavy metals. The treated soil meets toxicity characteristic leaching procedure (TCLP) criteria, and can be returned to the site or disposed of at a nonhazardous landfill. The granular activated carbon requires disposal after about 20 to 30 treatment cycles and should also pass TCLP criteria, simplifying disposal.

WASTE APPLICABILITY:

The soil leaching process can treat solid wastes generated by the wood preserving and metal plating industries, battery waste sites, and urban lead sites. The advantages of this process over traditional waste treatment schemes for chromated copper arsenate (CCA) wastes are as follows:

- Treated soils pass TCLP criteria and can be reapplied on site.
- Treatment by-products do not require disposal as hazardous waste.
- Land disposal of large volumes of soil is eliminated.
- Heavy metals are recovered by the ENVIRO-CLEAN process and can be reused by industry.

STATUS:

The Soil Leaching Process was accepted into the Emerging Technology Program in 1993. Laboratory-scale tests have shown that the process successfully treats soil contaminated with CCA. In 1992, Lewis treated a 5-gallon sample of CCA-contaminated soil from Hickson Corporation (Hickson), a major CCA chemical manufacturer. The treated soil passed TCLP criteria, with chromium and arsenic, the two main leach constituents, averaging 0.8 milligrams per kilogram (mg/kg) and 0.9 mg/kg, respectively. Analysis also revealed 3,330 milligrams per liter (mg/L) of chromium, 13,300 mg/L of copper, and 22,990 mg/L of iron in the leaching solution. In addition, analysis indicated 41.4 mg/L of chromium, 94.8 mg/L of copper, and 3.0 mg/L of arsenic present in the wash water. After treatment, the wash water contained metals levels below 0.1 mg/L for copper and chromium.

Lewis plans further laboratory-scale testing at its Pittsburgh, Pennsylvania facility, followed by bench- or pilot-scale testing at Hickson's facility in Conley, Georgia.

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The SITE Program assesses but does not approve or endorse technologies.

MATRIX PHOTOCATALYTIC INC.
(formerly NUTECH ENVIRONMENTAL)
(TiO_2 Photocatalytic Air Treatment)

TECHNOLOGY DESCRIPTION:

Matrix Photocatalytic Inc., formerly Nutech Environmental, is developing a titanium dioxide (TiO_2) photocatalytic air treatment technology that removes and destroys volatile organic compounds (VOC) and semivolatile organic compounds from air streams. During treatment, contaminated air at ambient temperatures flows through a fixed TiO_2 catalyst bed activated by light. Typically, organic contaminants are destroyed in fractions of a second.

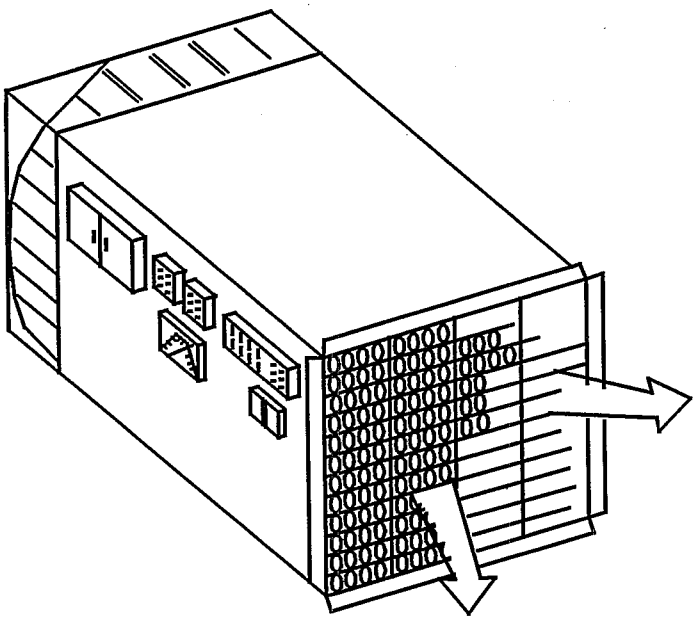
Major technology advantages include the following:

- Very robust equipment
- No residual toxins
- No ignition source
- Unattended operation
- Low direct treatment cost

The technology has been tested on benzene, toluene, ethylbenzene, and xylene; trichloroethene (TCE); tetrachlorethene (PCE); isopropyl alcohol; acetone; chloroform; methanol; and methyl ethyl ketone. Some full-scale and field-scale systems are shown in the figures below and on the next page, respectively.

WASTE APPLICABILITY:

The TiO_2 photocatalytic air treatment technology can effectively treat dry or moist air. The technology has been demonstrated to purify steam directly, thus eliminating the need to condense. Systems of 100 cubic feet per minute have been successfully tested on vapor extraction operations, air stripper emissions, steam from desorption processes, and VOC emissions from manufacturing facilities. Other potential applications include odor removal, stack gas



Full-Scale Photocatalytic Air Treatment System

The SITE Program assesses but does not approve or endorse technologies.

treatment, soil venting, and manufacturing ultra-pure air for residential, automotive, instrument, and medical needs. Systems up to about 1000 cubic foot per meter can be cost competitive with thermal destruction systems.

STATUS:

The TiO_2 photocatalytic air technology was accepted into SITE Emerging Technology Program in October 1992. Program advancements include the following:

- Ability to destroy carbon tetrachloride and other saturated compounds
- Sustained destruction of PCE and TCE of high concentration without generating phosgene
- Effective destruction of oxygenates (ketones, alcohols)

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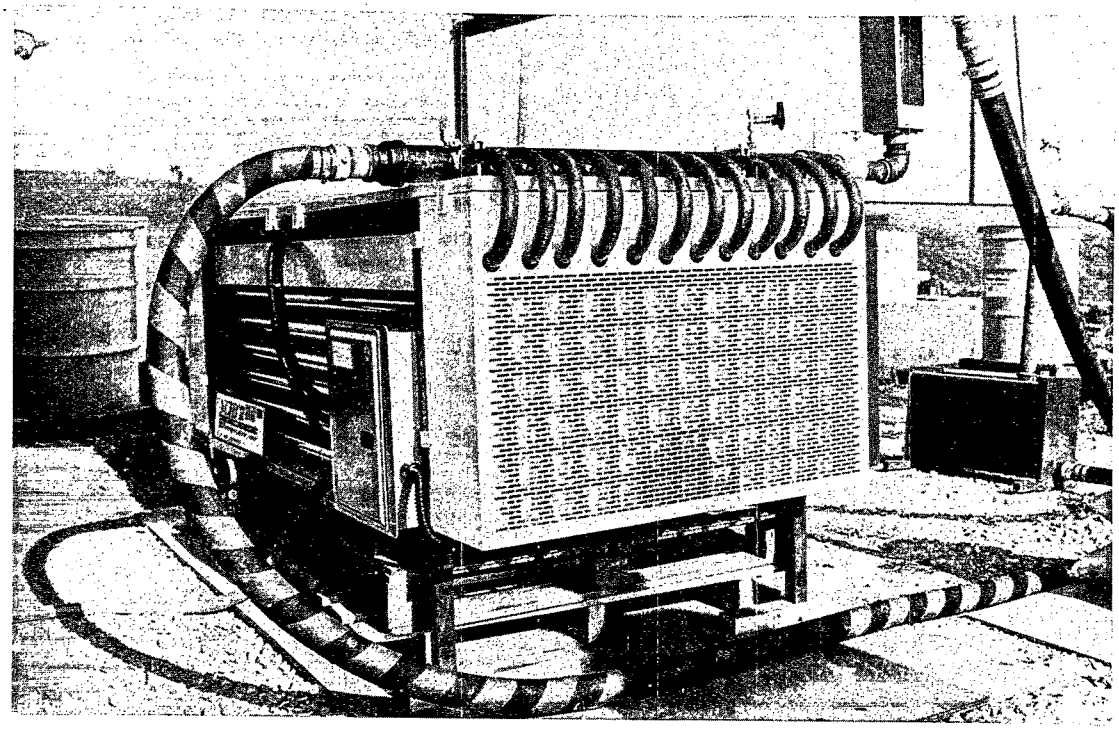


Field-Scale Photocatalytic Air Treatment System Treating TCE and PCE on a Soil Vapor Extraction Site at Savannah River

The SITE Program assesses but does not approve or endorse technologies.

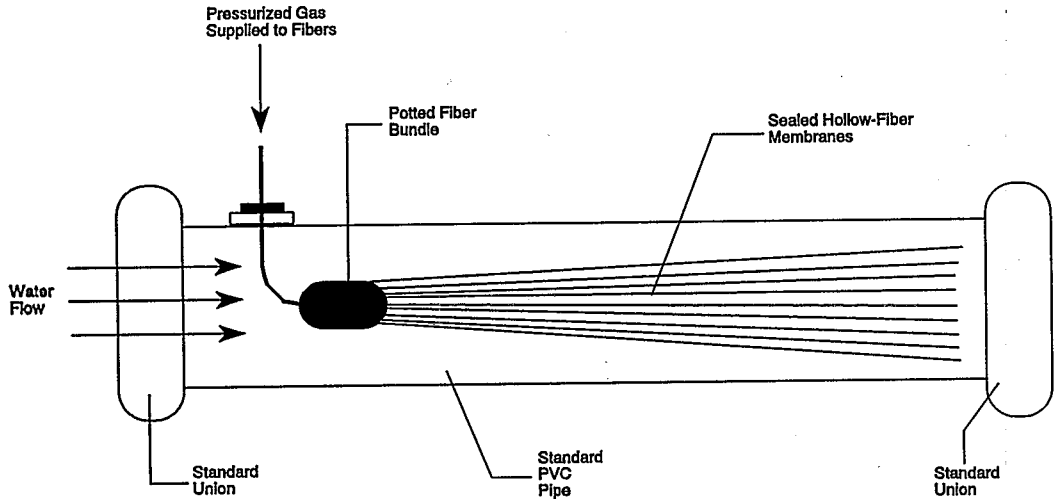
MEMBRAN CORPORATION
(Membrane Gas Transfer in Waste Remediation)

TECHNOLOGY DESCRIPTION:

Oxygen dissolution is a fundamental process in the design of aerobic biological treatment processes. Conventional gas dissolution devices produce a large quantity of small bubbles. These bubbles provide a large surface area across which gas transfer can take place. The limitations of bubble technologies include poor gas transfer efficiencies, poor performance control, and atmospheric release of volatile organic compounds. Membrane technology can dissolve gases without bubbles, eliminating many of the problems associated with conventional gas transfer devices.

A fluidized, hollow-fiber membrane technology can dissolve high concentrations of oxygen, methane, or hydrogen into water by exploiting the high gas permeabilities of hollow-fiber microporous membranes. Direct, bubble-free gas dissolution occurs in pipes, called modules, that contain thousands of sealed, hollow, gas-permeable fibers filled with pressurized pure gases (see figure below). The upstream ends of the fibers are potted into a manifold that distributes the pressurized gas to the inside of each hollow fiber. The downstream ends of the fibers are individually sealed so they can move freely in the turbulent waterflow inside the pipe. Gas diffuses across the fiber walls and dissolves directly into the flowing water. Gas-dissolution is controlled by changing the water flow rate and the gas pressure.

The membrane module's ability to dissolve high concentrations of gaseous substrates without using bubbles has several operational and economic advantages. First, bubble-free gas dissolution means that all of the gas applied to the device is dissolved, eliminating gas wastage. Second, since many hazardous compounds are volatile, the ability to supply oxygen to an aerobic bioreactor without bubbles means no emissions and no need for installation of costly air pollution control equipment. Third, combustible gases such as hydrogen and methane dissolve into water without bubbles and without a subsequent release of the bubbles into confined spaces. Consequently, the economic advantage



Schematic Diagram of a Membrane Bubbleless Gas-dissolution Device

The SITE Program assesses but does not approve or endorse technologies.

offered by these gaseous substrates can now be safely exploited.

The project has two major objectives. The first objective is to quantify the long-term gas transfer performance of various untreated and treated sealed hollow-fiber membranes in different adverse environments. The second objective is to determine the performance of the membrane devices in emission-free bioreactors that use oxygen, methane and oxygen, and hydrogen as gaseous substrates. These gases will be used in the bioreactors, because they offer substantial cost savings compared to alternative substrates in the biological treatment of petroleum hydrocarbons and chlorinated solvents.

WASTE APPLICABILITY:

The bubbleless gas-dissolution technology may be applied to the on-site biological treatment of various wastewaters, including contaminated groundwater, and to the in situ bioremediation of contaminated aquifers. The gas dissolved by the membrane technology determines the types of organic and inorganic contaminants that can be biodegraded. With oxygen, treatable biological contaminants include gasoline, creosote components, phenolics, and other petroleum hydrocarbons. With oxygen and methane, treatable biological contaminants include various halogenated aliphatic hydrocarbons such as trichloroethene (TCE), dichloroethene isomers, vinyl chloride, dichloroethane isomers, chloroform, and dichloromethane (methylene chloride). The biological processes that can be supported with hydrogen include denitrification (nitrate removal) of ground and surface waters and reductive dehalogenation of chlorinated compounds in contaminated water. Biological reductive dehalogenation treats tetrachloroethene, TCE, carbon tetrachloride, chloroform, and various polychlorinated biphenyl congeners.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1994.

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The SITE Program assesses but does not approve or endorse technologies.

OHM REMEDIATION SERVICES CORPORATION
(Oxygen Microbubble In Situ Bioremediation)

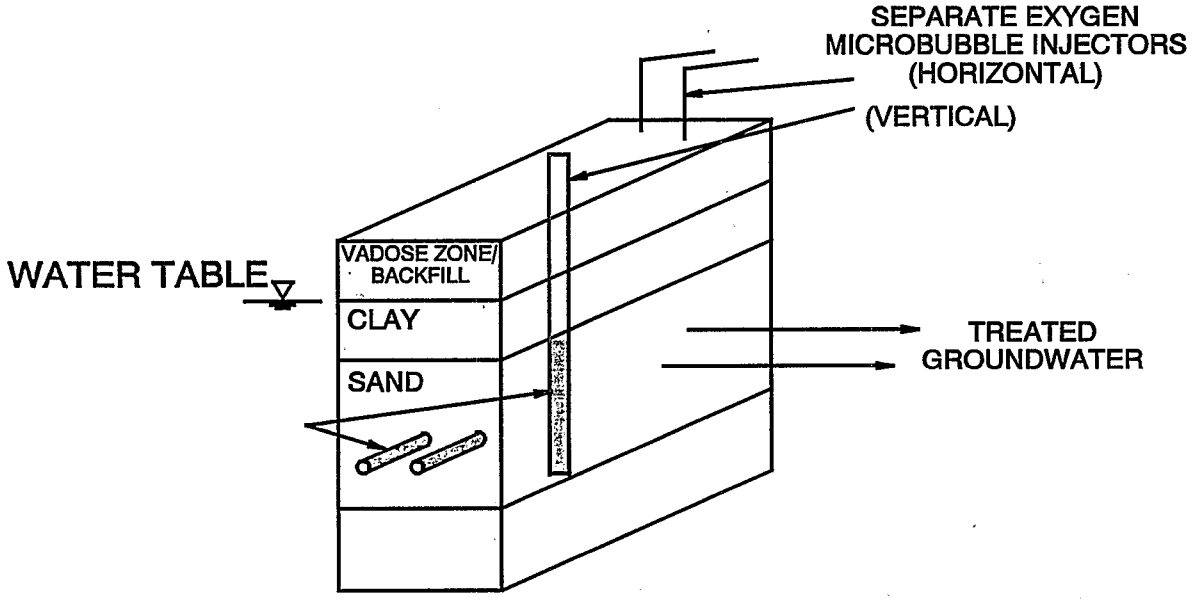
TECHNOLOGY DESCRIPTION:

This process uses oxygen microbubbles for in situ bioremediation of contaminated groundwater in the saturated zone. The difficulty with bioremediation lies in the delivery of oxygen, nutrients, and microorganisms to the treatment zone. Oxygen microbubbles can be continuously generated by mixing a concentrated surfactant stream with clean water under pressure to produce a 125- to 150-parts-per-million solution. This solution is then mixed with a continuous supply of oxygen under pressure. After passing through the generator, the resulting 65 percent dispersion of bubbles in the size range of 45 ± 40 microns can be delivered and injected into a saturated soil matrix under pressure.

The microbubble dispersion is pumped through a slotted, porous well delivery section into a laminated coarse sand or clay layer treatment zone. The oxygen microbubbles tend to flow into areas with high permeability, such as the coarser zones. Contaminated groundwater flows through the treatment zone and is bioremediated using the available oxygen. Indigenous microorganisms and indigenous or introduced nutrients provide the environment for in situ biodegradation of contaminants in groundwater or soil.

WASTE APPLICABILITY:

The process has successfully treated groundwater contaminated with a number of organic compounds including petroleum hydrocarbons, organic solvents, creosote, and pentachlorophenol.



Oxygen Microbubble In Situ Bioremediation of Groundwater

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

The Oxygen Microbubble In Situ Bioremediation process was accepted into the SITE Demonstration Program in summer 1992. This process will be demonstrated at a jet fuel spill site at Tyndall Air Force Base in Panama City, Florida.

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The SITE Program assesses but does not approve or endorse technologies.

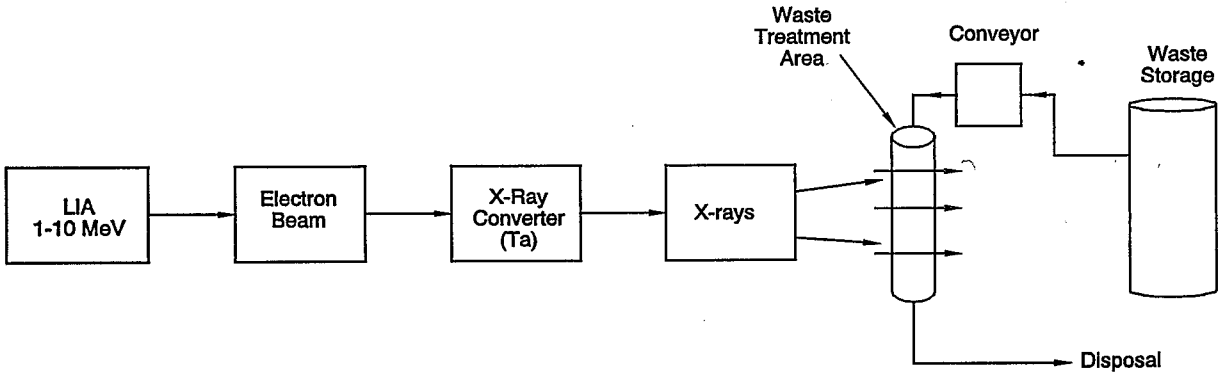
PULSE SCIENCES, INC.
(X-Ray Treatment of Organically Contaminated Soils)

TECHNOLOGY DESCRIPTION:

X-ray technology treatment of organically contaminated soils is based on in-depth deposition of ionizing radiation. Energetic photons (X-rays) collide with matter to generate a shower of lower energy secondary electrons within the contaminated waste material. These secondary electrons ionize and excite the atomic electrons, breaking up the complex contaminant molecules, and form radicals that react with contaminants to form compounds such as water, carbon dioxide, and oxygen. Other sources of ionizing radiation, such as ultraviolet radiation or direct electron processing, do not penetrate the treatable material deeply enough. Ultraviolet radiation heats only the surface layer, while a 1.5 million electron volt (MeV) electron penetrates about 4 millimeters into soil. X-rays, however, penetrate up to 20 centimeters, allowing treatment of thicker samples. In situ treatment, which reduces material handling requirements, may also be possible with X-ray treatment.

A high power linear induction accelerator (LIA) plus X-ray converter, shown in the figure below, generates the X-rays used in the treatment process. The LIA energy is between 1 MeV and 10 MeV; the upper limit depends on the application and is small enough to avoid activation. A pulse of electrons 50 to 100 nanoseconds long is directed onto a cooled high atomic number converter to efficiently generate X-rays. The X-rays penetrate and treat the organically contaminated soils.

The physical mechanism by which volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) are removed primarily depends on the contaminant present. Because of the moisture in contaminated soil, sludge, and sediments, the shower of secondary electrons resulting from X-ray deposition produces both highly oxidizing hydroxyl radicals and highly reducing aqueous electrons. While hazardous by-products may form during X-ray treatment, contaminants and by-products may be



X-Ray Treatment Process

The SITE Program assesses but does not approve or endorse technologies.

completely converted at sufficiently high dose levels without undesirable waste residuals or air pollution.

Since X-rays penetrate about 20 centimeters into soil, they can more easily treat large soil volumes, and standard container walls will not absorb a significant fraction of the ionizing radiation. X-rays can treat solid waste on a conveyor or waste contained in disposal barrels. Pulse Sciences, Inc., estimates that the cost of high throughput X-ray processing is competitive with alternative processes.

WASTE APPLICABILITY:

X-ray treatment of organically contaminated soils technology can potentially treat large numbers of contaminants with minimum waste handling or preparation. Treatable organic contaminants include benzene, toluene, xylene, trichloroethylene, tetrachloroethylene, carbon tetrachloride, chloroform, and polychlorinated biphenyls.

STATUS:

The X-ray treatment of organically contaminated soils technology was accepted into the SITE Emerging Technology Program in 1993. A 1.2 MeV, 800-amp, 50 watt LIA and a 10.8 MeV, 0.2 amp, 10,000 watt radio frequency (RF) linac will be used in the program. The program's primary objective is to demonstrate that X-ray treatment can reduce VOC and SVOC levels in soils to acceptable levels, and determine any hazardous by-product that may be produced.

Samples with identical initial contaminant concentration levels will be irradiated at increasing dose levels to determine 1) the rate (concentration versus dose) at which the contaminants are being destroyed, and 2) the X-ray dose required to reduce organic contamination to acceptable levels. The 10.8 MeV RF linac, which produces more penetrating X-rays, should provide information on the optimum X-ray energy for the treatment process. Increasing the accelerator energy allows a more efficient conversion from electrons to X-rays in the converter, but an upper limit (about 10 MeV) restricts the energy treatment, since higher energy activates the soil. The experimental database will develop a conceptual design and cost estimate for a high throughput X-ray treatment system.

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The SITE Program assesses but does not approve or endorse technologies.

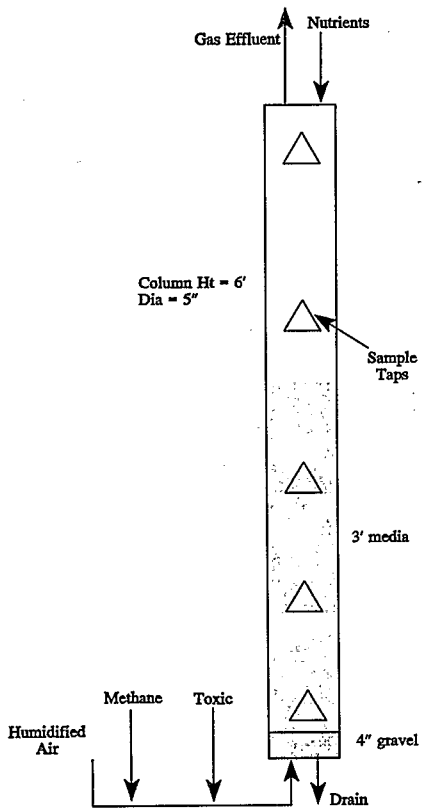
REMEDIATION TECHNOLOGIES, INC.
(Chlorinated Gas Treatment Biofilm Reactor)

TECHNOLOGY DESCRIPTION:

The Remediation Technologies, Inc., biological treatment technology uses aerobic cometabolic organisms in fixed-film biological reactors to treat gases contaminated with volatile chlorinated hydrocarbons. Contaminated gases enter the bottom of the 6-foot tall reactor column and flow up through a medium that has a high surface area and favorable porosity for gas distribution. Both methanotrophic and phenol-degrading organisms may be evaluated within the reactor (see figure below).

In methanotrophic columns, methane and nutrients are added to grow the organisms capable of degrading volatile chlorinated hydrocarbons. The organisms degrade these compounds into acids and chlorides that can be subsequently degraded to carbon dioxide and chloride. Because of intermediate toxicity and competitive inhibition, methane-volatile organic compound (VOC) feeding strategies are critical to obtain optimum VOC degradation over the long term.

Methanotrophic bacteria from various soils were tested to determine potential VOC compound degradation. The optimal culture from this testing was isolated and transferred to a bench-scale biofilm reactor, where substrate degradation rates per unit of biofilm surface area were determined. Four pilot-scale biofilters were then



Methanotrophic BioFilm Reactor

The SITE Program assesses but does not approve or endorse technologies.

established, with feeding strategies and retention times based on earlier testing.

The following issues are investigated in the methanotrophic biofilters:

- Comparison of different media types
- Trichloroethylene (TCE) removal across the columns
- TCE degradation rates

In addition to studies of the methanotrophic biofilters, a column was seeded with a filamentous phenol-degrading consortia that grows well on phenol in a nitrogen-limited solution. Phenol also induces enzymes capable of rapid cometabolic degradation of TCE.

WASTE APPLICABILITY:

This technology can treat gaseous streams of chlorinated volatile hydrocarbons. These waste streams may result from air stripping of contaminated groundwater or industrial process streams, or extracted gas from in situ site remediation by vacuum extraction.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in summer 1992. TCE degradation rates in the pilot-scale biofilter have been well below those previously measured in laboratory testing or those reported in the literature for pure cultures.

The phenol-fed column was started on a celite medium. TCE removal was superior to the methanotrophic columns, even with sub-optimal biomass development. Further testing is underway to determine optimal phenol-feeding strategies, TCE removal, degradation of other VOCs, and the effect of mixtures.

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The SITE Program assesses but does not approve or endorse technologies.

STATE UNIVERSITY OF NEW YORK AT OSWEGO
(Photocatalytic Degradation of PCB-Contaminated Sediments and Waters)

TECHNOLOGY DESCRIPTION:

The State University of New York at Oswego (SUNY) has developed a photocatalytic system that treats sediments contaminated with polychlorinated biphenyls (PCB) and other chlorinated organic contaminants. This system includes a reactor that consists of three chambers connected in series (see figure below). Each of the chambers is covered with a transparent material that allows sunlight and artificial light penetration.

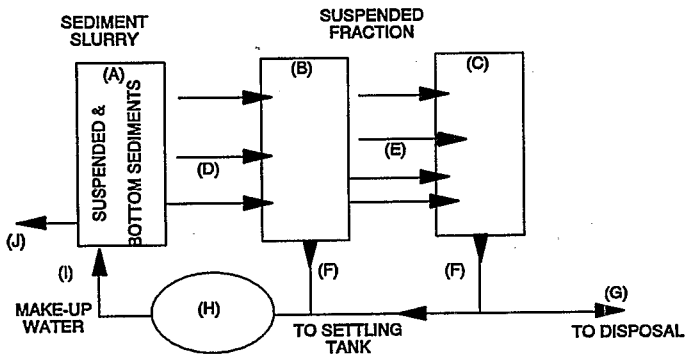
In Chamber A, the sediment is continuously agitated to allow separation of the suspended and bottom sediment fractions, and a titanium dioxide (TiO_2) catalyst is added. As agitation proceeds, the suspended fraction is irradiated at the slurry-air surface to promote photocatalysis.

The suspended sediment fraction is then slowly discharged to Chamber B, exposing the bottom sediments in Chamber A to the light sources. A tank baffle in Chamber A agitates the bottom sediments to maximize contact with the catalyst, promoting catalytic degradation.

Following continued treatment in Chamber B, the suspended sediment fraction is gravity-discharged to Chamber C, where additional TiO_2 is added for continued treatment and eventual discharge. The sediment can be recirculated through Chamber B if additional treatment is needed. When treatment is complete, the sediment is discharged to a settling tank or disposed of. Make-up water can be pumped back to Chamber A if needed. Once the bottom sediments in Chamber A are adequately treated, they are also removed for further treatment or disposal. Any gases produced during treatment are trapped with a vacuum system, which draws volatiles through a carbon filter.

This technology offers the following benefits over extraction, solidification/stabilization, and decomposition:

- The reactor can operate at ambient pressure and temperature without organic solvents additions.
- The catalyst, TiO_2, is environmentally inert.
- The photocatalytic process can use sunlight or artificially produced ultraviolet light.
- The technology requires little energy and may be applied in situ.
- The technology can also treat contaminated dredge materials by subjecting the contaminated sediments to the photocatalytic process as an integral part of the dredging operation.



PCB Treatment System

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

This technology is designed to treat sediment contaminated with PCBs and other chlorinated organic contaminants on site. The technology may reduce levels of PCBs to below detection limits, or it may be used as a pretreatment in conjunction with technologies like microbial degradation.

Although this technology was developed to degrade PCB-contaminated sediments, the process can also treat a host of other organically contaminated solids, including volatile and semivolatile organic compounds. The technology can also pretreat inorganically contaminated solids such as soils and sludges.

STATUS:

SUNY was accepted into the SITE Emerging Technology Program in 1993. During experiments conducted from June to September 1992, the photocatalytic technology reduced PCBs in sediment by 62 and 68 percent after 4 and 6 hours of sunlight irradiation, respectively. SUNY also conducted experiments on PCB-contaminated sediments from a Massena, New York area federal Superfund Site. The technology degraded more than 90 percent of the PCBs in a 48-hour period. In August 1994, a second generation pilot-scale photoreactor was constructed at a state Superfund Site. This reactor is self-contained, mobile, and capable of treating up to 2 tons of contaminated soils and/or sediments in batch mode (see figure below). The second generation photoreactor uses a mixing motor to agitate sediment. Contaminants and the catalyst are exposed to artificial lights immediately below the reactor cover at the slurry-air interface. In October 1994, the pilot-scale photoreactor degraded PCB-contaminated casting sands at a state Superfund Site.

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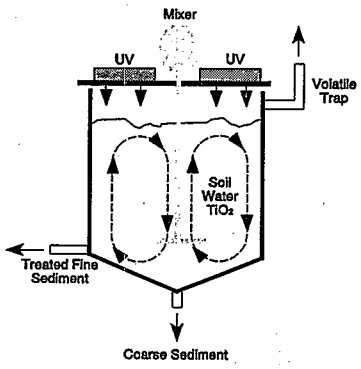


Cross-Sectional Schematic of Three-Phased Treatment of Contaminated Sediments

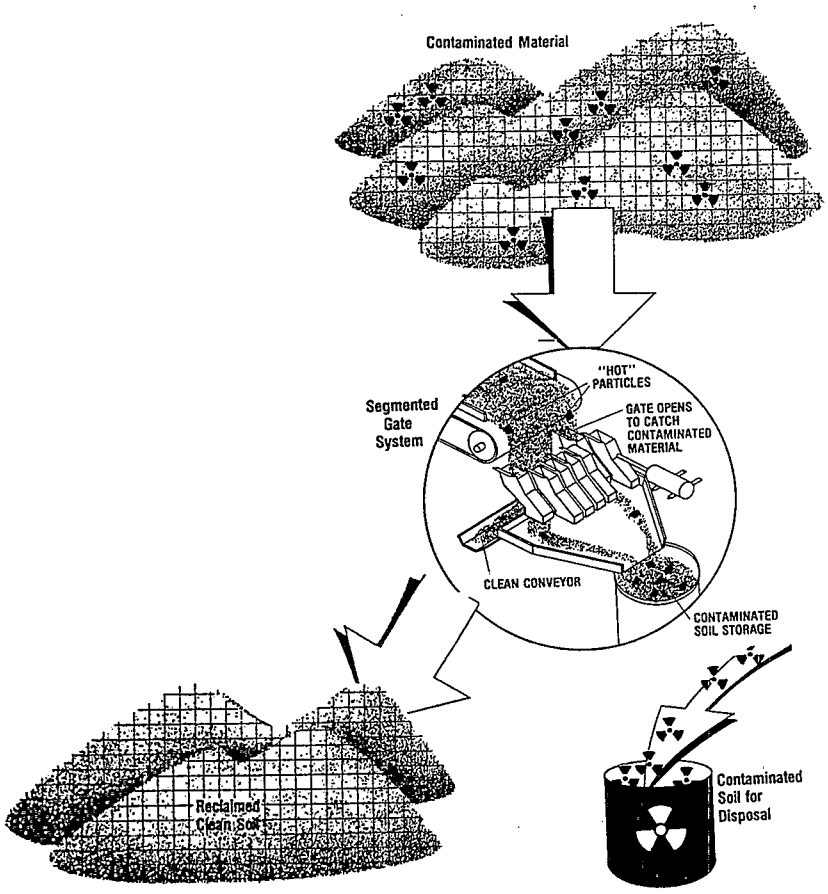
The SITE Program assesses but does not approve or endorse technologies.

THERMO ANALYTICAL
(Segmented Gate System [SGS])

TECHNOLOGY DESCRIPTION:

TMA has conducted many radiological surveys of soil contaminated with low and intermediate levels of radioactivity. Cleanup of these sites is a highly labor-intensive process requiring numerous personnel to conduct radiological surveys with portable hand-held instruments. When contamination is encountered, an attempt is made to manually excise it. When surveys disclose larger areas of contamination, heavy equipment is used to remove the contaminated material. Since it is difficult to perform pinpoint excision with earthmoving equipment, large amounts of uncontaminated soil are removed along with the contaminant. Few sites have been characterized to be uniformly and/or homogeneously contaminated above release criteria over the entire site area.

As a result, TMA developed the Segmented Gate System (SGS) to physically separate and segregate radioactive material from otherwise "clean" soil. The SGS removes only a minimal amount of clean soil with the radioactive particles, significantly reducing the overall amount of material requiring disposal. The SGS works by conveying radiologically-contaminated feed



TMA's Segmented Gate System

The SITE Program assesses but does not approve or endorse technologies.

material on moving conveyor belts under an array of sensitive radiation detectors. The moving material is assayed, and radioactivity content is logged. Copyrighted computer software tracks the radioactive material as it is transported by the conveyor, and triggers a diversion by one or more of the Segmented Gate chutes when the material reaches the end of the conveyor. Clean soil goes in one direction, and contaminated material in another.

The key advantage to this system is automation, which affords a much higher degree of accuracy compared to manual methods. Contaminants can be isolated and removed by locating small particles of radioactive material dispersed throughout the soil. All of the soil is analyzed continuously during processing to document the level of radioactivity in the waste and to demonstrate that cleaned soil meets release criteria. This automation and analysis results in a significant cost reduction for special handling, packaging, and disposal of the site's radioactive waste.

WASTE APPLICABILITY:

The SGS locates, analyzes, and removes gamma-ray emitting radionuclides from soil, sand, dry sludge, or any host matrix that can be transported by conveyor belts. The SGS can identify hot particles, which are assayed in units of picoCuries, and can quantify distributed radioactivity, which is assayed in units of picoCuries per gram (pCi/g) of host material. The lower limit of detection (LLD) for the system is dependent on the ambient radiation background, conveyor belt speed, thickness of host material on conveyor, and contaminant gamma-ray energy and abundance. However, LLDs for americium-241 of 2 pCi/g and for radium-222 of 5 Pci/g have been successfully demonstrated.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1994. A similar system has been used on Johnston Atoll, Guam since January 1, 1992, and is currently under contract to the Defense Nuclear Agency to process coral soil contaminated with plutonium and americium. Pilot- and field-scale tests using TMA-owned mobile equipment are planned for federal and commercial sites in the continental U.S. beginning January 1995. These tests will demonstrate the technology's applicability to other radionuclides and other host matrices.

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The SITE Program assesses but does not approve or endorse technologies.

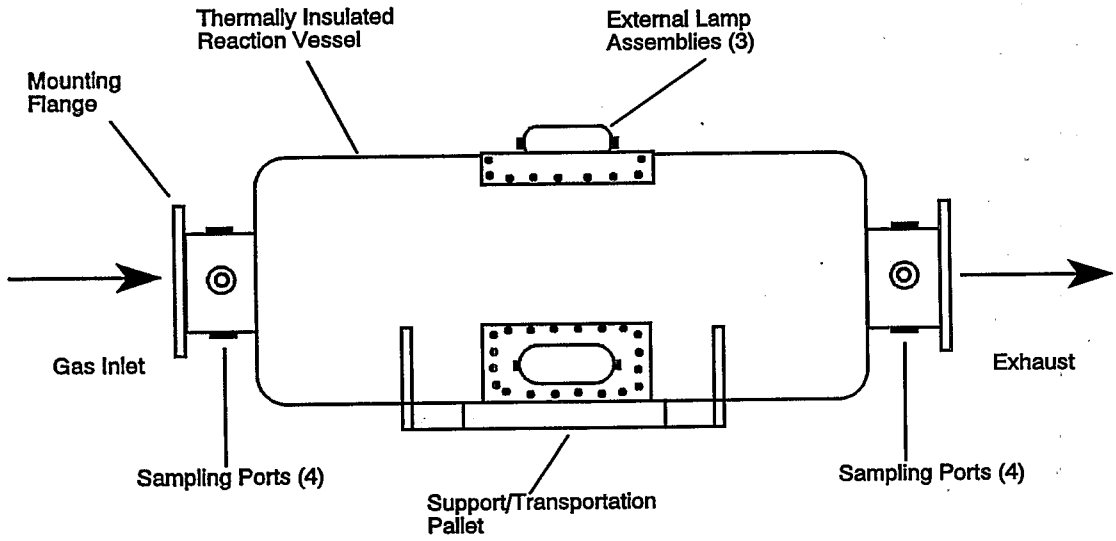
UNIVERSITY OF DAYTON RESEARCH INSTITUTE
(Photothermal Detoxification Unit)

TECHNOLOGY DESCRIPTION:

Photolytic reactions (reactions induced by exposure to ultraviolet (UV) light) can destroy certain hazardous organic wastes at relatively low temperatures. Unfortunately, attempts to exploit these reactions for large-scale hazardous waste remediation have experienced only limited success. Specifically, most photochemical processes offer relatively limited throughput rates and exhibit an inability to completely mineralize the targeted wastes. For special cases, such as aqueous waste streams, these problems have been partially addressed by using indirect photochemical reactions involving a highly reactive photolytic initiator such as hydrogen peroxide or heterogeneous catalysts. Recently, the University of Dayton Research Institute developed a photolytic detoxification process that is clean and efficient and offers the speed and general applicability of a combustion process.

The photothermal detoxification unit (PDU) uses photothermal reactions conducted at temperatures higher than those used in conventional photochemical processes (200 to 500 degrees Celsius [°C] versus 20 °C), but lower than combustion temperatures (typically greater than 1,000 °C). At these elevated temperatures, photothermal reactions are energetic enough to destroy wastes quickly and efficiently without producing complex and potentially hazardous byproducts.

The PDU is a relatively simple device, consisting of an insulated reactor vessel illuminated with high-intensity UV lamps. As shown in the figure below, the lamps are mounted externally for easy maintenance and inspection. Site remediation technologies that generate high temperature gas streams, such as thermal desorption or in situ steam stripping, can incorporate the PDU with only slight equipment modifications. The PDU can be equipped with a preheater for use with low temperature extraction technologies. Furthermore, the PDU can be equipped with conventional air pollution control devices for removal of acids and suspended particulates from the treated process stream. The PDU shown in the figure is also equipped



Photothermal Detoxification Unit (PDU)

The SITE Program assesses but does not approve or endorse technologies.

with built-in sampling ports for monitoring and quality assurance and quality control.

WASTE APPLICABILITY:

The PDU has proven extremely effective at destroying the vapors of polychlorinated biphenyls, polychlorinated dibenzodioxins, polychlorinated dibenzofurans, aromatic and aliphatic ketones, and aromatic and chlorinated solvents, as well as brominated and nitrous wastes found in soil, sludges, and aqueous streams. The PDU can be incorporated with most existing and proposed remediation processes for clean, efficient, on-site destruction of the off-gases. More specifically, high-temperature processes can directly incorporate the PDU; low-temperature vapor extraction technologies can use the PDU fitted with a preheater; and groundwater remediation processes can use the PDU in conjunction with air stripping.

STATUS:

The technology was accepted into the Emerging Technology Program in August 1992, and development work began in December 1992. Through prior programs with the U.S. Department of Energy, the process's effectiveness has been thoroughly investigated using relatively long wavelength UV light, which is concentrated sunlight with wavelengths greater than 300 nanometers). Limited data have also been generated at shorter wavelengths (higher energy) using available industrial UV illumination systems.

Emerging Technology Program data indicated that the technology performs as expected for chlorinated aromatic wastes, such as dichlorobenzene and tetrachlorodibenzodioxin, and better than expected for relatively light chlorinated solvents, such as trichloroethylene (TCE) and tetrachloroethylene. Further tests with selected mixtures, including benzene, toluene, ethylbenzene, xylene, TCE, dichlorobenzene, and water vapor, show that the process is effective at treating wastes typically found in many remediation sites. Adequate scaling and performance data are now available to proceed with the design and development of prototype full-scale units for field testing and evaluation.

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The SITE Program assesses but does not approve or endorse technologies.

UNIVERSITY OF HOUSTON
(Concentrated-Chloride Extraction and Recovery of Lead)

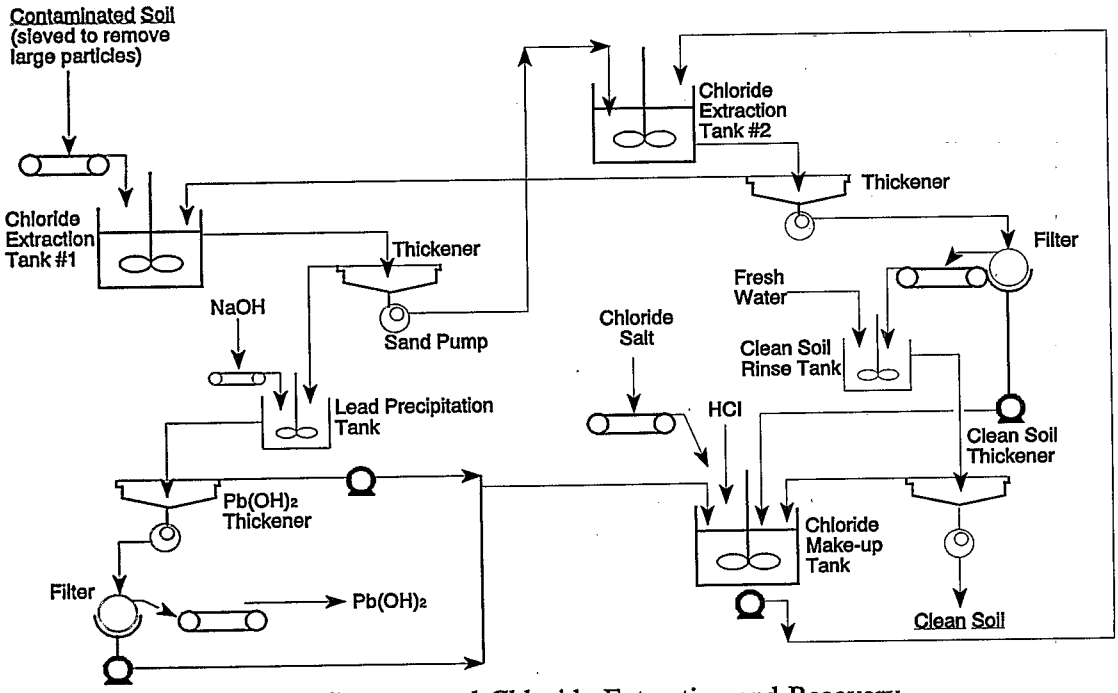
TECHNOLOGY DESCRIPTION:

This technology is designed to recover lead from soils using an aqueous solvent extraction process. The extraction process takes advantage of the high solubility of chloro-complexes of lead. The figure below depicts a counter-current extraction process that may be used in a pilot-scale unit.

First, soil is sieved to remove particles greater than 4 millimeters in diameter. The soil is then placed in the chloride extraction tank and extracted with concentrated (greater than 4 molar) chloride solution with a residence time of less than 1 hour (perhaps less than 15 minutes). This slurry then enters a thickener. The bottoms of the thickener are sent by a sand pump to the second chloride extraction tank, where they contact fresh solvent.

After contacting fresh solvent for less than one hour, the solution exiting the second chloride extraction tank is sent to the second thickener. The bottoms of the second thickener are sent to the soil rinse system to remove excess salt before the clean soil is placed back on site. The overflows from the second thickener are sent to the first chloride extraction tank, and the overflows from the first thickener are sent to the lead precipitation system. After lead hydroxide is removed, the spent chloride solution is sent to the solvent makeup unit, where it is prepared for reuse. This system will operate in a continuous fashion and is expected to treat up to 10 kilograms per hour (kg/hr) of soil at pilot-scale.

Concentrated-chloride extraction has been used on actual lead battery waste site (LBWS) soil at laboratory scale. Lead removals of greater than 97 percent were achieved on LBWS soil conta-



Concentrated Chloride Extraction and Recovery of Lead Process for Soil Treatment

The SITE Program assesses but does not approve or endorse technologies.

minated with up to 20 percent lead using only a single-step sodium chloride (NaCl) batch extraction. Following these NaCl extraction tests, the treated soils consistently passed the toxicity characteristic leaching procedure test.

This project's main objective is to scale up the extraction process to a mobile, pilot-scale unit after optimizing the process at laboratory scale. Four preliminary project goals are to 1) optimize the technology at laboratory scale by determining the effects of varying several process parameters, 2) determine the extraction process mechanism, 3) examine the ability of the process to decontaminate lead-contaminated soils of different soil types, and 4) determine the ability to recycle and reuse the lead-saturated chloride solution. The pilot-scale unit will be designed, constructed, and demonstrated after the project goals have been achieved.

WASTE APPLICABILITY:

This technology removes lead from soil, particularly at battery waste sites. However, this project will also study the feasibility of removing lead from other wastes and removing metals such as cadmium, mercury, silver, copper, and zinc from contaminated soil.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1994. The University of Houston will conduct bench-scale experiments to determine the optimum operating parameters for a pilot-scale unit. Once optimum operating conditions are determined, a mobile pilot-scale unit will be constructed to treat up to 10 kg/hr of soil. Two LBWS in the Houston are being considered for the pilot-scale tests.

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The SITE Program assesses but does not approve or endorse technologies.

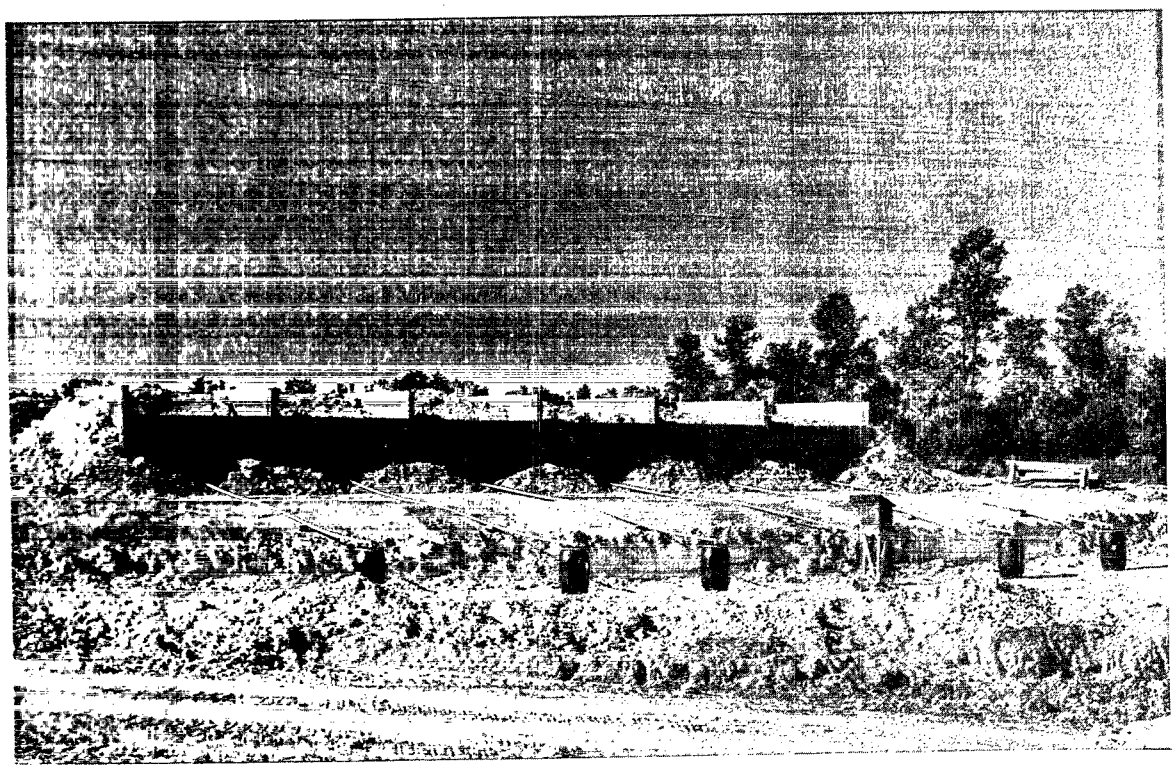
UNIVERSITY OF SOUTH CAROLINA
(In Situ Mitigation of Acid Water)

TECHNOLOGY DESCRIPTION:

The in situ acid water mitigation process addresses the acid drainage problem associated with exposed sulfide-bearing minerals from sources including mine waste rock and abandoned metallic mines. Acid drainage forms under natural conditions when iron disulfides are exposed to the atmosphere and water, spontaneously oxidizing them to produce a complex of highly soluble iron sulfates and salts. These salts hydrolyze to produce an acid-, iron-, and sulfate-enriched drainage that adversely affects the environment.

The in situ mitigation strategy modifies the hydrology and geochemical conditions of the site through land surface reconstruction and selective placement of limestone.

Limestone is used as the alkaline source material because it has long-term availability, is generally inexpensive, and is safe to handle. For the chemical balances to be effective, the site must receive enough rainfall to produce seeps or drainages that continually contact the limestone. Rainfall, therefore, helps to remediate the site, rather than increasing the acid drainage.



Overview of Site Lysimeters

The SITE Program assesses but does not approve or endorse technologies.

During mine construction, surface depressions and limestone chimneys are installed to collect surface runoff and funnel it into the waste rock dump. Acidic material is capped with impermeable material to divert water from the acid cores. With this design, the net acid load will be lower than the alkaline load, resulting in benign, nonacid drainage.

WASTE APPLICABILITY:

The technology mitigates acid drainage from abandoned waste dumps and mines. It can be applied to any site in a humid area where limestone is available.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in March 1990. Six large-scale lysimeters (12 feet wide, 8 feet high, and 16 feet deep) were constructed and lined with 20-mil polyvinyl chloride plastic (see photograph on previous page). The lysimeters drained through an outlet pipe into 55-gallon collection barrels. Piezometers in the lysimeter floor monitored the hydrology and chemistry of the completed lysimeter. During June 1991, 50 tons of acid-producing mine waste rock were packed into each lysimeter.

The effluent from each lysimeter was monitored for 1 year to establish a quality baseline. In the second phase of the study, selected lysimeters were topically treated, maintaining two lysimeters as controls to compare the efficacy of the acid abatement strategy. In addition, a rain gauge was installed at the site for mass balance measurements. An ancillary study correlating laboratory and field results is complete. In the last phase of the 3-year study, little if any leachate was collected due to drought conditions in the Southeast.

With the return of normal rainfall, sufficient leachate was collected to compare the treated cells against the controls to evaluate the treatment's effectiveness. The treated cells, in general, showed a 20 to 25 percent reduction in acid formation. The acidities measured about 10,000 milligrams per liter (mg/L) for the untreated bins, while acidities from the treated bins measured about 7,000 mg/L. This study was conducted on a very high acid-producing waste rock, representing almost a worst-case situation. The process should be more successful on milder acid sources.

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The SITE Program assesses but does not approve or endorse technologies.

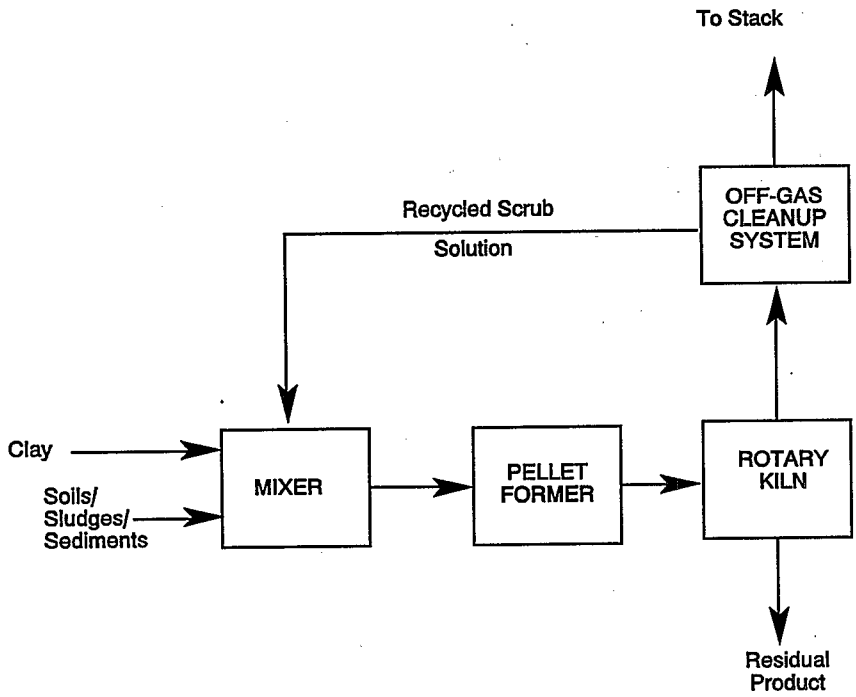
WESTERN PRODUCT RECOVERY GROUP, INC.
(CCBA Physical and Chemical Treatment)

TECHNOLOGY DESCRIPTION:

The coordinate, chemical bonding and adsorption (CCBA) process converts heavy metals in soils, sediments, and sludges to nonleaching silicates. The process can also oxidize organics in the waste stream and incorporate the ash into the ceramic pellet matrix (see figure below). The solid residual consistency varies from a soil and sand density and size distribution to a controlled size distribution ceramic aggregate form. The residue can be placed back in its original location, or used as a substitute for conventional aggregate. The process uses clays with specific cation exchange capacity as sites for physical and chemical bonding of heavy metals to the clay.

The process is designed for continuous flow. The input sludge and soil stream are carefully ratioed with specific clays and then mixed in a high intensity mechanical mixer. The mixture is then densified and formed into green or unfired pellets of a desired size. The green pellets are then direct-fired in a rotary kiln for approximately 30 minutes. The pellet temperature slowly rises to 2,000 degrees Fahrenheit (°F), creating the fired pellet's ceramic nature. Organics on the pellet's surface are oxidized, and organics inside the pellet are pyrolyzed as the temperature rises. As the pellets reach 2,000 °F, the available silica sites in the clay chemically react with the heavy metals in the soil and sludge to form the final metal silicate product.

The process residue is an inert ceramic product, free of organics, with metal silicates providing the molecular bonding structure to preclude leaching. The kiln off-gas is processed in an afterburner and wet scrub system before it is released into the atmosphere. Excess scrub



CCBA Process

The SITE Program assesses but does not approve or endorse technologies.

solution is recycled to the front-end mixing process.

WASTE APPLICABILITY:

The CCBA process has been demonstrated commercially on metal hydroxide sludges at a throughput of 70 wet tons per month, based on an 8-hour day, at 25 percent by solid weight. This process can treat wastewater sludges, sediments, and soils contaminated with most mixed organic and heavy metal wastes.

STATUS:

The CCBA process was accepted into the SITE Emerging Technology Program in January 1991. Under this program, the CCBA technology will be modified to include soils contaminated with both heavy metals and most organics. The initial SITE studies will be completed at a pilot facility with a capacity of 10 pounds per hour; the resulting data will then be used to design a transportable production unit.

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The SITE Program assesses but does not approve or endorse technologies.

ROY F. WESTON, INC.
(Ambersorb® 563 Adsorbent)

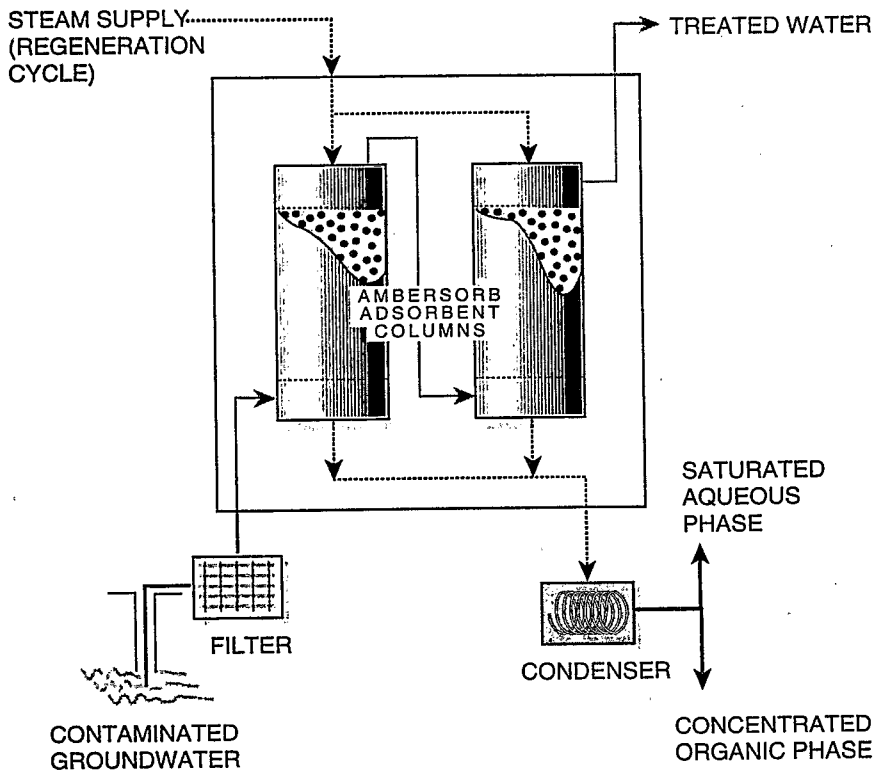
TECHNOLOGY DESCRIPTION:

The Ambersorb® 563 adsorbent is a regenerable adsorbent that treats groundwater contaminated with hazardous organics (see figure below). Ambersorb 563 adsorbent has 5 to 10 times the capacity of granular activated carbon (GAC) for low concentrations of volatile organic compounds (VOC).

Current GAC adsorption techniques are well established for groundwater remediation, but require either disposal or thermal regeneration of the spent carbon. In these cases, the GAC must be removed from the site and shipped as a hazardous material to the disposal or regeneration facility.

Ambersorb 563 adsorbent has unique properties that result in several key performance benefits:

- Ambersorb 563 adsorbent can be regenerated on site using steam, thus eliminating the liability and cost of off-site regeneration or disposal associated with GAC treatment. Condensed contaminants are recovered through phase separation.
- Because Ambersorb 563 adsorbent has a much higher capacity for volatile organics than GAC (at low concentrations), the process can operate for significantly longer service cycle times before regeneration is required.



Ambersorb® 563 Adsorbent

The SITE Program assesses but does not approve or endorse technologies.

- Ambersorb 563 adsorbent can operate at higher flow rate loadings compared with GAC, which translates into a smaller, more compact system.
- Ambersorb 563 adsorbents are hard, nondusting, spherical beads with excellent physical integrity, eliminating handling problems and attrition losses typically associated with GAC.
- Ambersorb 563 adsorbent is not prone to bacterial fouling.
- Ambersorb 563 adsorbents have extremely low ash levels.

In addition, the Ambersorb 563 carbonaceous adsorbent-based remediation process could eliminate the need to dispose of by-products. Organics can be recovered in a form potentially suitable for immediate reuse. For example, removed organics could be burned for energy in a power plant. Reclamation of waste organics is an important benefit, as recovered materials could be used as resources instead of disposed of as wastes.

This combination of benefits may result in a more cost-effective alternative to currently available treatment technologies for low-level VOC-contaminated groundwater.

WASTE APPLICABILITY:

Ambersorb 563 adsorbent is applicable to any water stream containing contaminants that can be treated with GAC, such as 1,2-dichloroethane, 1,1,1-trichloroethane, tetrachloroethene, vinyl chloride, xylene, toluene, and other VOCs.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in 1993. Field demonstration testing was conducted in spring and summer 1994. Results will be available in late 1994.

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The SITE Program assesses but does not approve or endorse technologies.

MONITORING AND MEASUREMENT TECHNOLOGIES PROGRAM

The purpose of the Monitoring and Measurement Technologies Program (MMTP) is to accelerate the development, demonstration, and use of innovative monitoring, measurement, and characterization technologies at Superfund sites. These technologies are used to assess the nature and extent of contamination and evaluate the progress and effectiveness of remedial actions. The MMTP places high priority on technologies that provide cost-effective, faster, and safer methods than conventional technologies for producing real-time or near-real-time data.

The MMTP is interested in new or modified technologies that can detect, monitor, and measure hazardous and toxic substances in the surface (soil and sediment), subsurface (saturated and vadose zones), air, biological tissues, wastes, and surface waters, as well as technologies that characterize the physical properties of sites. Technologies of interest include chemical sensors for in situ measurements; groundwater sampling devices; soil and core sampling devices; soil gas sampling devices; fluid sampling devices for the vadose zone; in situ and field-portable analytical methods; and other systems that support field sampling or data acquisition and analysis.

The identification of candidate technologies is ongoing; therefore, technology developers are encouraged to submit new and updated information at any time. This information is reviewed, cataloged, and incorporated into a technology matrix, from which EPA makes a preliminary determination of possible candidates for participation. Developers interested in participating should contact Stephen Billets at 703-798-2232.

Evaluations or demonstrations have been completed for 27 projects in the MMTP. These technologies are presented in alphabetical order in Table 4, and are included in the technology profiles that follow.

TABLE 5

Completed SITE Monitoring and Measurement Technologies Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Analytical and Remedial Technology, Inc., Menlo Park, CA	Automated Volatile Organic Analytical System	D. MacKay 415-324-2259	Stephen Billets 702-798-2272	Water, Air Streams	Not Applicable	VOCs
Asoma Instruments, Moorpark, CA	Model 200 XRF Analyzer	Bob Friedl 805-529-7123	Harold Vincent 702-798-2129	Solids, Liquids, Slurries, Powders, Pastes, Films	Nonspecific Inorganics	Not Applicable
Bruker Instruments, Billerica, MA	Bruker Mobile Environmental Monitor	John Wronka 508-667-9580	Stephen Billets 702-798-2272	Air Streams, Water, Soil, Sludge, Sediment	Not Applicable	VOCs, SVOCs, PCBs, and PAHs
Dexsil Corporation, Hamden, CT (2 Demonstrations)	Environmental Test Kits	Steve Finch 203-288-3509	J. Lary Jack 702-798-2373	Soil, Sediment, Transformer Oils	Not Applicable	PCBs
EnSys, Inc., Research Triangle Park, NC (2 Demonstrations)	Penta RISc Test System	Aisling Scallan 919-941-5509	J. Lary Jack 702-798-2373	Groundwater, Soil	Not Applicable	PCP
Geoprobe Systems, Salina, KS	Geoprobe Conductivity Sensor	Collin Christy or Tom Christy 913-825-1842	J. Lary Jack 702-798-2373	Soil, Rock, Hydrogeologic Fluids	Nonspecific Inorganics	Nonspecific Organics
Graseby Ionics, Ltd., and PCP, Inc., Watford, Hertsfordshire, England/West Palm Beach, FL (2 Demonstrations)	Ion Mobility Spectrometry	John Brokenshire 011-44-923-816166 Martin Cohen 407-683-0507	Eric Koglin 702-798-2432	Air Streams, Vapor, Soil, Water	Not Applicable	VOCs
HNU Systems, Inc., Newton, MA	HNU-Hanby PCP Test Kit	Jack Driscoll 617-964-6690	J. Lary Jack 702-798-2373	Soil	Not Applicable	PCPs
HNU Systems, Inc., Newton, MA	HNU Source Excited Fluorescence Analyzer-Portable (SEFA-P) XRF Analyzer	Jack Driscoll 617-964-6690	Harold Vincent 702-798-2272	Solids, Liquids, Slurries, Powders	Nonspecific Inorganics	Not Applicable
HNU Systems, Inc., Newton, MA	Portable Gas Chromatograph	Ed Lazaruck 617-964-6690	Richard Berkley 919-541-2439	Air Streams	Not Applicable	VOCs, Aromatic Compounds, Halocarbons

TABLE 5 (Continued)

Completed SITE Monitoring and Measurement Technologies Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Idetek, Inc. (formerly Binax Corporation, Antox Division), Sunnyvale, CA	Equate® Immunoassay	Richard Lankow 408-752-1353	Jeanette Van Emon 702-798-2154	Water	Not Applicable	Aromatic Hydrocarbons
MDA Scientific, Inc. Norcross, GA	Fourier Transform Infrared Spectrometer	Orman Simpson 404-242-0977	William McClenny 919-541-3158	Air Streams	Nonspecific Inorganics	Nonspecific Organics
Microsensor Systems, Incorporated, Bowling Green, KY	Portable Gas Chromatograph	N. L. Jarvis 410-939-1089	Richard Berkley 919-541-2439	Air Streams	Not Applicable	VOCs
Millipore Corporation, Bedford, MA	EnviroGard™ PCB Immunoassay Test Kit	Alan Weiss 617-275-9200	J. Lary Jack 702-798-2373	Soil, Water	Not Applicable	PCBs
Millipore Corporation, Bedford, MA	EnviroGard™ PCP Immunoassay Test Kit	Alan Weiss 617-275-9200	J. Lary Jack 702-798-2373	Soil, Water	Not Applicable	PCPs
MTI Analytical Instruments (formerly Microsensor Technology, Incorporated), Fremont, CA	Portable Gas Chromatograph	Mark Brunf 510-490-0900	Richard Berkley 919-541-2439	Air Streams	Nonspecific Inorganics	Nonspecific Organics
Ohmicron Corporation, Newtown, PA	Pentachlorophenol RaPID Assay	Mary Hayes 215-860-5115	J. Lary Jack 702-798-2373	Soil, Water	Not Applicable	PCPs
Outokumpu Electronics, Inc., Langhorne, PA	Metorex X-MET 920P XRF Analyzer	James Pasmore 800-229-9209	Harold Vincent 702-798-2129	Solids, Liquids, Slurries, Powders, Films	Nonspecific Inorganics	Not Applicable
Photovac International, Inc., Deer Park, NY	Photovac 10S PLUS	Mark Collins 516-254-4199	Richard Berkley 919-541-2439	Air Streams	Not Applicable	VOCs
SCITEC Corporation, Kennewick, WA	Metal Analysis Probe (MAP®) Portable Assayer	Mike Mullin 800-466-5323 509-783-9850	Harold Vincent 702-798-2129	Soil, Sediment, Filter and Wipe Samples	Nonspecific Inorganics, Lead	Non Applicable
Sentex Sensing Technology, Inc., Ridgefield, NJ	Scentograph Portable Gas Chromatograph	Amos Linenberg 201-945-3694	Richard Berkley 919-541-2439	Air Streams	Not Applicable	VOCs

TABLE 5 (Continued)

Completed SITE Monitoring and Measurement Technologies Program Projects as of October 1994

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
SRI Instruments, Torrance, CA	Gas Chromatograph	Dave Quinn 310-214-5092	Richard Berkley 919-541-2439	Air Streams	Not Applicable	VOCs
TN Technologies, Inc., Round Rock, TX	Spectrace 9000 X-Ray Fluorescence Analyzer	Margo Meyers 512-388-9100	Harold Vincent 702-798-2129	Soil, Sediment, Filter and Wipe Samples	Nonspecific Inorganics, Lead	Not Applicable
Tri-Services, Aberdeen Proving Ground, MD	Site Characterization Analysis Penetrometer System (SCAPS)	George Robitialle 410-671-1576 John Ballard 601-634-2446	J. Lary Jack 702-798-2373	Soil	Not Applicable	Petroleum, PAHs, VOCs
Unisys Corporation, Eagon, MN	Rapid Optical Screen Tool	David Bohne 612-456-2339 Garry Hubbard 612-456-3721	J. Lary Jack 702-798-2373	Soil	Not Applicable	Petroleum, PAHs, VOCs
United States Environmental Protection Agency, Las Vegas, NV	Field Analytical Screening Program PCB Method	Howard Fribush 703-603-8831	J. Lary Jack 702-798-2373	Soil, Water	Not Applicable	PCBs
XonTech Incorporated, Van Nuys, CA	XonTech Sector Sampler	Matt Young 818-787-7380	Joachim Pleil 919-541-4680	Air Streams	Not Applicable	VOCs

ANALYTICAL AND REMEDIAL TECHNOLOGY, INC.
(Automated Volatile Organic Analytical System)

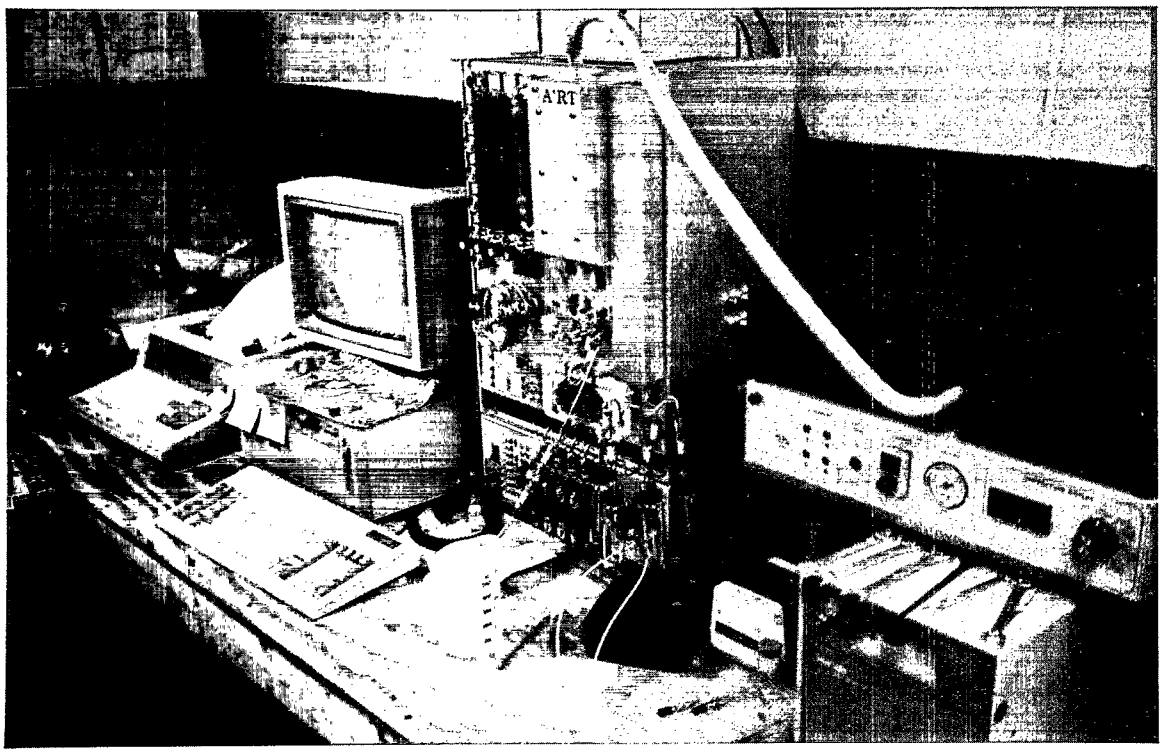
TECHNOLOGY DESCRIPTION:

The automated volatile organic analytical system (AVOAS) permits continuous monitoring of a water stream. The instrument consists of a sampling manifold that automatically samples at predetermined collection points (see photograph below). The samples are then shunted directly into a chamber where volatile organic compounds (VOC) are purged from the sample. These purged VOCs are collected on a sorbent trap, which is then thermally desorbed. These desorbed compounds are automatically injected into a gas chromatograph, where individual components are separated.

The gas chromatograph can be equipped with a variety of detectors that offer high sensitivity or specificity depending on the application or data requirements. The entire system, including report preparation, is under computer control; therefore, the operator is not directly involved in sample collection, transport, or analysis. The instrument was designed to meet the requirements of standard EPA purge-and-trap methods.

WASTE APPLICABILITY:

The AVOAS system is designed for automated determination of volatile organic compounds in aqueous samples, such as those obtained from a treatment or process stream. Because the system contains a thermal desorption chamber, air samples collected on TENAX or charcoal tubes may also be analyzed. The instrument can provide real-time analytical data during remediation and long-term monitoring phases at a Superfund site.



Automated Volatile Organic Analytical System (AVOAS)

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

The AVOAS system was demonstrated in May 1991 at the Wells G and H Superfund site in EPA Region 1. The demonstration was conducted as part of a pilot-scale pump-and-treat technology study. For purposes of this demonstration, the AVOAS' analytical results were compared to results obtained using EPA Method 502.2. The system was installed to collect samples at six points in the treatment train. Duplicate samples were collected and shipped to a conventional laboratory for confirmatory analysis.

A preliminary evaluation of the results indicates a strong correlation between the laboratory and field data. A full report on this demonstration was prepared in December 1991. The results were presented at the 1992 Pittsburgh Conference and Exposition on Analytical Chemistry and Applied Spectroscopy. Additional studies will be conducted to expand the scope of application and to prepare detailed protocols based on the conclusions and recommendations in the final report.

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The SITE Program assesses but does not approve or endorse technologies.

ASOMA INSTRUMENTS
(Model 200 XRF Analyzer)

TECHNOLOGY DESCRIPTION:

The ASOMA Model 200 X-ray fluorescence (XRF) analyzer is a field portable bench-top unit. It can simultaneously analyze six inorganic elements ranging from aluminum to uranium. The Model 200 XRF analyzer is compact and lightweight, and does not require liquid nitrogen. The Model 200 XRF analyzer can operate with a car battery or a battery pack, allowing the XRF unit to be used at remote sites where electricity is not available.

The Model 200 XRF analyzer uses a proportional counter detector to provide high elemental resolution and low detection limits. Two radioisotope excitation sources provide a broad range of excitation energies to identify and quantify inorganic elements.

The Model 200 XRF analyzer provides high sample throughput and is reportedly easy to operate. Analytical results obtained by this instrument are reportedly comparable to the results obtained by EPA-approved methods.

WASTE APPLICABILITY:

The Model 200 XRF analyzer can detect inorganic elements in solids, liquids, slurries, powders, pastes, and films, including air particulates on filters. The XRF analyzer can identify inorganic elements at concentrations ranging from parts per million to percentage levels.

STATUS:

The ASOMA Model 200 XRF analyzer has been used at a number of Superfund sites across the country. A SITE demonstration of the ASOMA Model 200 XRF analyzer is scheduled for February 1995.

Model 200 XRF Analyzer

The SITE Program assesses but does not approve or endorse technologies.

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The SITE Program assesses but does not approve or endorse technologies.

BRUKER INSTRUMENTS
(Bruker Mobile Environmental Monitor)

TECHNOLOGY DESCRIPTION:

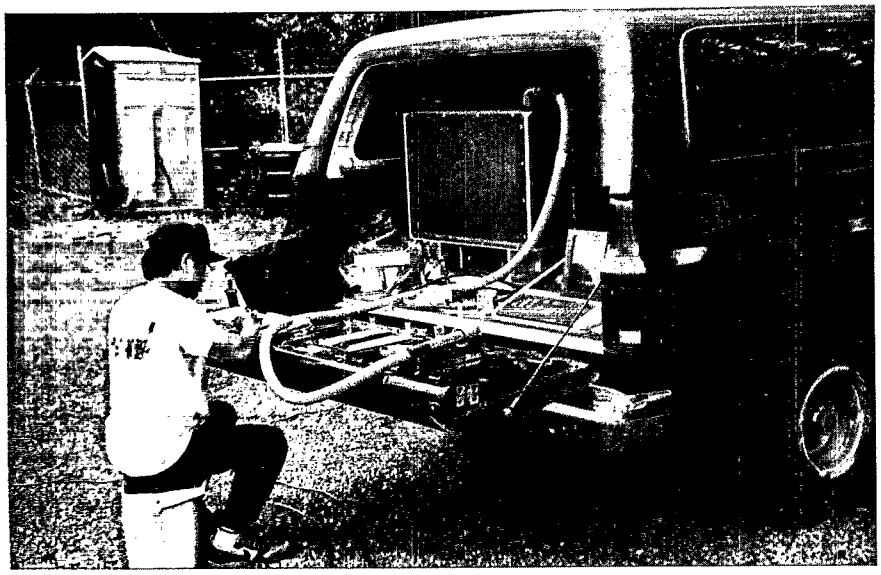
The Bruker mobile environmental monitor is a field transportable mass spectrometer designed to identify and measure organic pollutants in various environmental media (see photograph below). The spectrometer uses a quadruple mass analyzer similar to most conventional instruments. Like conventional mass spectrometers, this instrument can identify and quantify organic compounds on the basis of their retention time, molecular weight, and characteristic fragment pattern. The Bruker instrument's design and electronics are specially designed for field use.

The instrument is designed to operate with battery power and can be used in various environmental situations with minimum support requirements. The integrated gas chromatograph allows introduction of complex extracts for separation into individual components and subsequent analysis in the mass spectrometer.

The instrument was originally designed for the military to detect and monitor chemical warfare agents. Environmental samples may be introduced to the mass spectrometer through the direct air sampler or the gas chromatograph. Results are collected and stored in a computer, where data is reduced and analyzed. The computer provides reports within minutes of final data acquisition.

WASTE APPLICABILITY:

This instrument is designed to detect the full range of volatile and semivolatile organic com-



Bruker Mobile Environmental Monitor

The SITE Program assesses but does not approve or endorse technologies.

pounds directly in air and in water, soil, sediment, sludge, and hazardous waste extracts. The Bruker mobile environmental monitor provides in-field, real-time support during the characterization and remediation phases of cleanup at a hazardous waste site.

STATUS:

This technology was demonstrated at the ReSolve, Inc., and Westborough Superfund site in EPA Region 1. The technology was used to analyze polychlorinated biphenyls and polynuclear aromatics in soil and the full range of Superfund-targeted volatile organic compounds in water. Splits of all samples analyzed in the field were shipped to a laboratory for confirmatory analysis using standard Superfund analytical methods.

The SITE demonstration was completed in September 1990, and a project report was provided to the Superfund Program Office. The results of this study were presented at the American Society for Mass Spectrometry (ASMS) Conference in May 1991 and at the Superfund Hazardous Waste Conference in July 1991. A recent survey of regional laboratories identified additional testing of this technology as a priority need.

The Environmental Monitoring Systems Laboratory-Las Vegas purchased this field portable gas chromatograph/mass spectrometer system in fiscal year 1992 to pursue other applications and to expand the scope of this project.

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The SITE Program assesses but does not approve or endorse technologies.

DEXSIL CORPORATION
(Environmental Test Kits)

TECHNOLOGY DESCRIPTION:

The Dexsil Corporation (Dexsil) produces two test kits that detect polychlorinated biphenyls (PCB) in soil: the Dexsil Clor-N-Soil PCB Screening Kit, and the Dexsil L2000 PCB/ Chloride Analyzer. The Dexsil Clor-N-Soil PCB Screening Kit (see figure below) extracts PCBs from soil and dissociates the PCBs with a sodium reagent, freeing chloride ions. These ions then react with mercuric ions to form mercuric chloride compound. The extract is then treated with diphenylcarbazone, which reacts with free mercuric ions to form a purple color. The less purple the color, the greater the concentration of PCBs in the extract.

The Dexsil L2000 PCB/Chloride Analyzer (see figure on next page) also extracts PCBs from soil and dissociates the PCBs with a sodium reagent, freeing chloride ions. The extract is then analyzed with a calibrated chloride-specific electrode. The L2000 instrument then translates the output from the electrode into parts per million (ppm) PCB concentration.

These technologies produce analytical results at different data quality levels. The Clor-N-Soil PCB Screening Kit identifies samples above or below a single concentration, which is generally tied to regulatory action levels. The Dexsil L2000 PCB/Chloride Analyzer quantifies specific concentrations of PCBs in a sample over the range of 2 to 2000 ppm. The applicability of these methods depends on the data quality needs of a specific project. Both technologies can be used on site for site characterization or removal action.

Dexsil Clor-N-Soil PCB Screening Kit

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The Dexsil Clor-N-Soil PCB Screening Kit and the Dexsil L2000 PCB/Chloride analyzer can detect PCB concentrations in soil, sediment, and transformer oils.

STATUS:

These test kits were demonstrated at a PCB-contaminated facility in EPA Region 7. About 200 soil samples were collected and analyzed on site using the Dexsil test kits. Soil samples were not dried prior to analysis. Split samples were submitted to the off-site formal laboratory for confirmatory analysis by SW-846 Method 8080. Demonstration data were used to evaluate the accuracy and precision of the test kits, relative to internal quality control samples and to formal laboratory data. These data were also used to determine operating costs.

The sampling and field analyses for this technology demonstration were completed in August 1992. The final report is undergoing peer review and will be published in early 1995.

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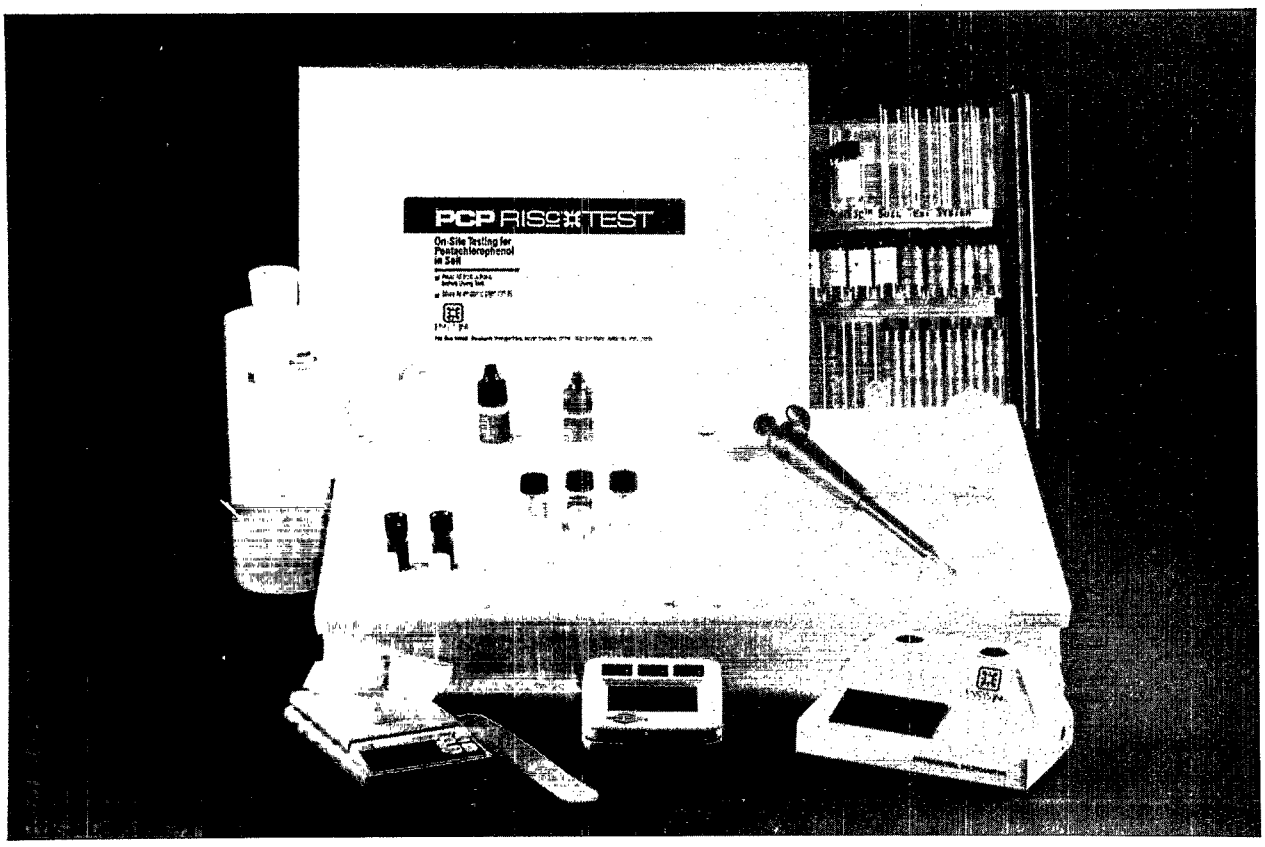
The SITE Program assesses but does not approve or endorse technologies.

ENSYS, INC.
(Penta RISc Test System)

TECHNOLOGY DESCRIPTION:

The Penta RISc Test Systems are designed to quickly provide semiquantitative results for pentachlorophenol (PCP) concentrations in soil and water samples. The technology uses immunoassay chemistry to produce compound-specific reactions that detect and quantify PCP. Polyclonal antibodies fix to the inside wall of a test tube, where they offer binding sites for PCP. An enzyme conjugate containing a PCP derivative is added to the test tube to compete with sample PCP for antibody binding sites. Excess sample and enzyme conjugate are washed from the test tube. Reagents are then added to the test tube to react with the enzyme conjugate, forming a color. After a designated time period, a solution is added to the test tube to stop color formation. The sample color is compared to the color formed by a PCP standard. A differential photometer compares the colors. The results obtained from soil samples are compared against three calibrators of 0.5, 5, and 50 parts per million (ppm). The technology's three calibrators for water are listed as 5, 500, and 5,000 parts per billion (ppb).



Penta RISc Test System

The SITE Program assesses but does not approve or endorse technologies.

The system can be affected by naturally occurring matrix effects such as humic acids, pH, or salinity. Site-specific matrix effects that can affect the system include: PCP carriers such as petroleum hydrocarbons or solvents; and other chemicals used in conjunction with PCP, including creosote, copper-chromium-arsenate, or herbicides. Specific chemicals similar in structure to PCP can provide positive results, or cross reactivity.

WASTE APPLICABILITY:

The PCP immunoassay measures PCP concentrations in soil and water. For soil analysis, the semiquantitative ranges are: greater than 50 ppm, between 50 and 5 ppm, between 5 and 0.5 ppm, and less than 0.5 ppm. For water analysis, the ranges are as follows: greater than 5,000 ppb, between 5,000 and 500 ppb, between 500 and 5 ppb, and less than 5 ppb. Ensys, Inc. can customize these ranges to a user's needs.

STATUS:

The SITE demonstration occurred at Morrisville, North Carolina. Samples collected from Winona, Missouri were transported to the demonstration location for testing. Samples from both sites were analyzed to evaluate the effects of different sample matrices, and different PCP carriers such as diesel fuel and isopropyl ether-butane. The demonstration was held during summer 1993 and consisted of analyzing 112 soil samples and 16 water samples.

The draft of the Technology Evaluation Report for the PCP test was submitted to EPA in spring 1994. The draft of the report is undergoing peer review and will be released in final report form in January 1995.

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The SITE Program assesses but does not approve or endorse technologies.

GEOPROBE SYSTEMS
(Geoprobe Conductivity Sensor)

TECHNOLOGY DESCRIPTION:

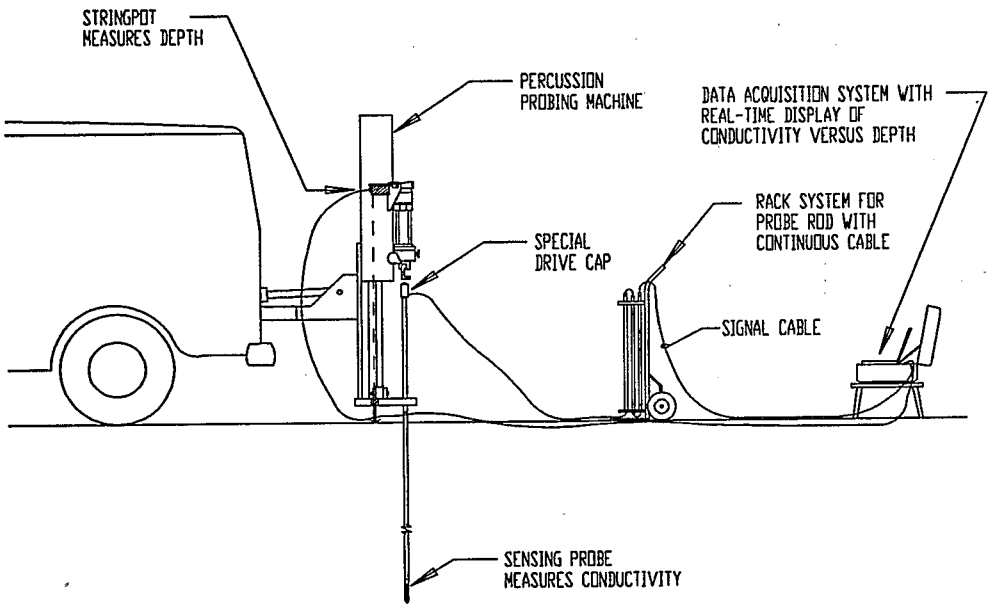
The Geoprobe conductivity sensor identifies lithology and potential contamination by measuring the electrical conductivity of soil, rock, and hydrogeologic fluids. Overall, soil and rock are resistant to current. Therefore, the ability of a hydrogeologic section to conduct a current is closely tied to the amount and types of pore fluids, and to the amount of dissolved solids in these fluids.

The conductivity sensor uses an isolated array of sensing rings to measure this conductivity. The probe is principally designed to help determine subsurface stratigraphy. Since layers of pure organic product, including hydrocarbons, alter the conductivity of a matrix, the probe may also help characterize subsurface contamination.

The principal components of the Geoprobe system are:

- a Geoprobe hydraulic punch
- standard sampling rods supplied with the system
- a cable threaded through the sampling rod that introduces the current
- the conductivity sensor
- a data receiver connected to a personal computer to record the probe's measurements

The hydraulic punch uses a combination of pushing and hammering to advance 3-feet-long segments of 2.54-centimeter-diameter hollow steel sampling rods. The conductivity sensor is attached to the lead section of the sampling rod.



Schematic Diagram of the Geoprobe Conductivity Sensor

The SITE Program assesses but does not approve or endorse technologies.

The conductivity sensor consists of four stainless steel contact rings fitted around a central steel shaft. Plastic electronically isolates the contact rings from the steel shaft, improving soil contact with the stainless steel rings. A hollow steel rod extends above the uppermost stainless-steel ring, housing a shielded signal cable that connects the contact rings with an external power source, measurement system, and data logging system.

The conductivity sensor can be used in a Dipole array or a Schlumberger array. The Dipole array is used when greater resolution is required. The Schlumberger array is generally used when optimal soil-to-probe contact cannot be maintained.

Geoprobe offers a training course for operating the conductivity sensor, but details are unavailable at this time. No maintenance or cost information is available for the technology at this time.

WASTE APPLICABILITY:

The Geoprobe conductivity sensor was designed to determine subsurface stratigraphy and to qualitatively indicate the presence or absence of contamination in subsurface soils.

STATUS:

The Geoprobe conductivity sensor field demonstration was conducted in September 1994.

After completing the demonstration, a Technology Evaluation Report (TER) will be prepared. The TER will present the results of the demonstration objectively and provide supporting documentation. In addition, an innovative technology evaluation report will be prepared and published that summarizes the findings presented in the TER. These reports will help data users and technology reviewers assess the performance of each technology for possible use on future site characterization or remediation projects at hazardous waste sites.

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The SITE Program assesses but does not approve or endorse technologies.

GRASEBY IONICS, LTD., and PCP, INC.
(Ion Mobility Spectrometry)

TECHNOLOGY DESCRIPTION:

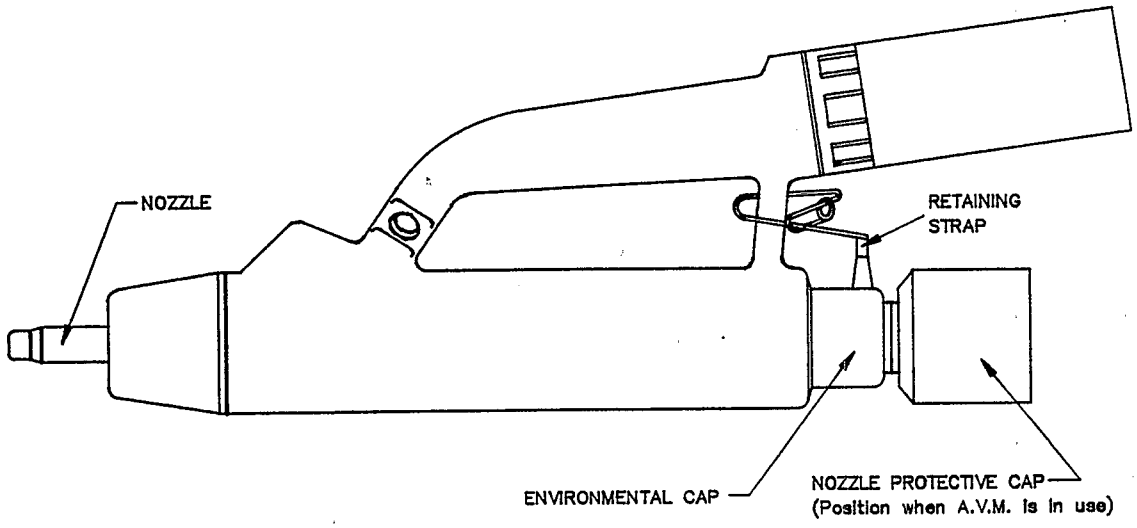
Ion mobility spectrometry (IMS) is a technique used to detect and characterize organic vapors in air. IMS involves the ionization of molecules and their subsequent temporal drift through an electric field. Analysis and characterization are based on analyte separations resulting from ionic mobilities rather than ionic masses; this difference distinguishes IMS from mass spectrometry. IMS operates at atmospheric pressure, a characteristic that has practical advantages over mass spectrometry, including smaller size, lower power requirements, less weight, and ease of use.

WASTE APPLICABILITY:

The IMS units, which are intended to be used in a preprogrammed fashion, can monitor chloroform, ethylbenzene, and other volatile organic compounds (VOC), in a defined situation. IMS units can analyze air, vapor, soil, and water samples. However, for analysis of liquid and solid materials, the contaminants must be introduced to the instrument in the gas phase, requiring some sample preparation.

STATUS:

Graseby Ionics, Ltd. (Graseby), and PCP, Inc., participated in a laboratory demonstration in summer and fall 1990. Graseby used a commercially available, self-contained instrument that weighs about 2 kilograms (kg) (see figure below). PCP, Inc., used a larger (12 kg) transportable IMS. This laboratory demonstration was the first opportunity to test the instruments, on environmental samples. Though IMS' potential is known, the results of the laboratory demonstration highlighted, for the first time, the technology's limitations. The following two



Airborne Vapor Monitor

The SITE Program assesses but does not approve or endorse technologies.

needs must be satisfied before IMS will be ready for field applications:

- Additional development of sampling or sample preparation strategies for soil and water analysis
- Improvements in the design and performance of IMS inlets in conjunction with the development of sampling and presentation procedures

FOR FURTHER INFORMATION:

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The SITE Program assesses but does not approve or endorse technologies.

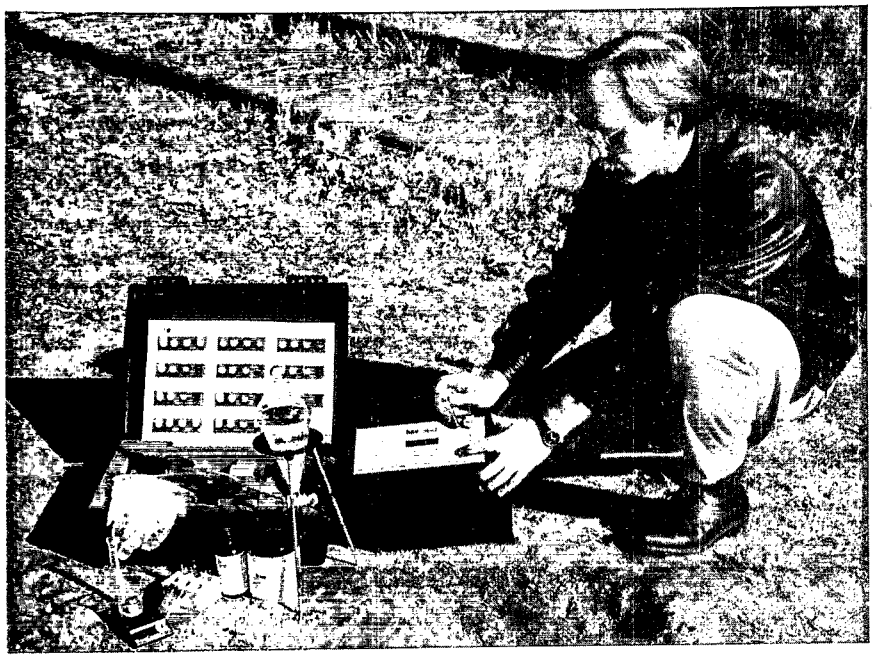
HNU SYSTEMS, INC.
(HNU-Hanby PCP Test Kit)

TECHNOLOGY DESCRIPTION:

The HNU-Hanby pentachlorophenol (PCP) test kit rapidly analyzes for PCP in soil samples. The test kit estimates PCP concentrations in samples when the carrier solvent is a petroleum hydrocarbon. The test kit can only detect those PCP carriers that contain aromatic compounds. The test kit estimates PCP concentrations in soil samples indirectly by measuring petroleum hydrocarbon carrier solvent for the PCP. The carrier solvent concentration to PCP concentration ratio must be constant for the test kit results to be usable.

To quantify the PCP results, split samples are used for confirmatory laboratory determination of PCP concentrations using EPA-approved methods. The confirmatory laboratory results and test kit results can generate calibration data by correlating two sets of data. As the number of samples and data points increase, the accuracy of the test kit results should improve.

The test kit uses the Friedel-Crafts alkylation reaction to detect aromatics and petroleum in soil samples. An electrophile is formed by the reaction of a Lewis acid catalyst, such as aluminum chloride, with an alkyl halide. Electrophile aromatic substitution products are generally very large molecules with a high degree of electron dislocation that causes intense coloring. When testing, the sample's color is compared to site-specific color standards for a semiquantitative assessment of PCP concentrations. Alternatively, the color change can be read by a reflective photometer. The reflective photometer used with calibration charts can provide quantitative results for PCP.



HNU-Hanby PCP Test Kit

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The PCP test kit measures PCP carriers that contain aromatic and petroleum hydrocarbons in soils. The method assumes a consistent ratio of PCP to carrier solvent. The method indirectly measures PCP concentrations with carrier solvents at a detection level of 1.0 parts per million for aromatic compounds.

STATUS:

The HNU-Hanby PCP test kit was used to screen and quantify PCP contamination in soils for a SITE demonstration. The screening kit was demonstrated in Morrisville, North Carolina in August 1993, with samples collected from Winona, Missouri.

The method was found to produce Level 1 quality assurance data during the demonstration. When PCP was present the test kit always detected the PCP. However, this result may be attributed to the abundance of petroleum carriers in the samples.

HNU Systems recently introduced a similar method that could measure PCP more directly by detecting chlorinated compounds in soil and water. This method works on the same principle as the method to detect aromatic compounds, only the method is conducted in reverse. The chlorinated compounds are originally present in the soil or water and an aromatic compound is introduced as a catalyst to allow the Friedel-Crafts reaction to proceed. The new method is also a colorimetric method.

The draft of the Technology Evaluation Report for the PCP test was submitted to EPA in spring 1994. The draft of the report is undergoing peer review and will be released in final report form in January 1995.

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The SITE Program assesses but does not approve or endorse technologies.

HNU SYSTEMS, INC.
(HNU Source Excited Fluorescence Analyzer-Portable [SEFA-P] XRF Analyzer)

TECHNOLOGY DESCRIPTION:

The HNU Source Excited Fluorescence Analyzer-Portable (SEFA-P) X-ray fluorescence (XRF) analyzer is a field portable unit. It can simultaneously analyze a number of inorganic elements ranging from sodium to uranium. It requires liquid nitrogen for detector operation; but once filled can operate for over 8 hours. A rechargeable battery allows the XRF unit to be used at remote sites where electricity is not available.

The HNU SEFA-P XRF analyzer uses a silicon-lithium detector to provide high elemental resolution and low detection limits. Three radioisotope excitation sources provide a broad range of excitation energies to identify and quantify inorganic elements.

The HNU SEFA-P XRF analyzer provides high sample throughput and is reportedly easy to operate. Analytical results obtained by this instrument are reportedly comparable to the results obtained by EPA-approved methods.

WASTE APPLICABILITY:

The HNU SEFA-P XRF analyzer can detect inorganic elements in solids, liquids, slurries, and powders. The analyzer can identify inorganic elements at concentrations ranging from parts per million to percentage levels.

STATUS:

The HNU SEFA-P XRF analyzer has been used at a number of Superfund sites across the country. A SITE demonstration of the HNU SEFA-P XRF analyzer is scheduled for February 1995.

The SITE Program assesses but does not approve or endorse technologies.

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The SITE Program assesses but does not approve or endorse technologies.

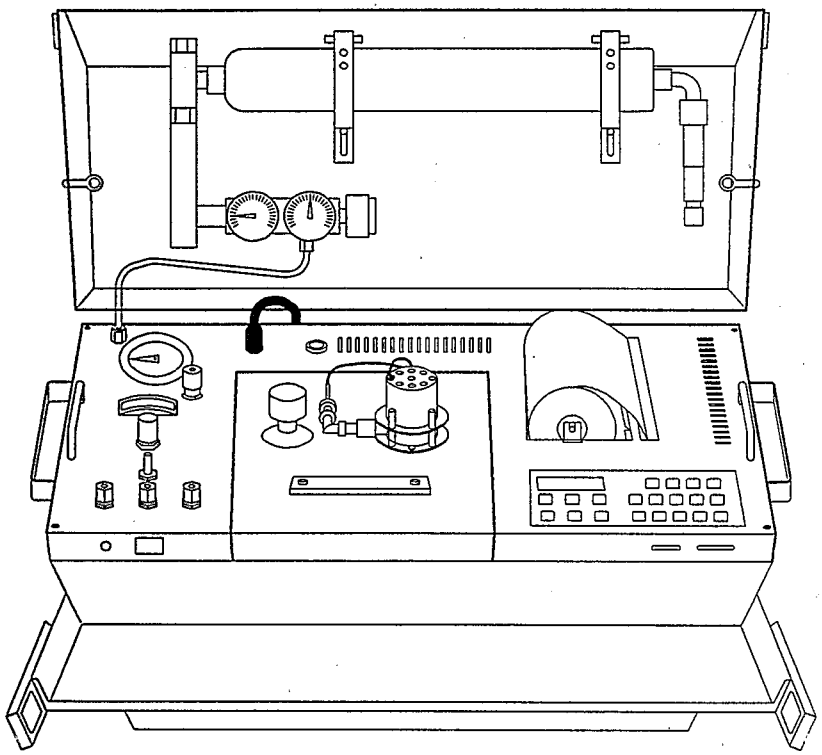
HNU SYSTEMS, INC.
(Portable Gas Chromatograph)

TECHNOLOGY DESCRIPTION:

The field-deployable HNU GC 311 portable isothermal gas chromatograph monitors volatile organic compound emissions from hazardous waste sites and other emissions sources before and during remediation (see figure below). It has an internal carrier gas supply, operates on 110-volt line power, and is microprocessor-controlled. An internal printer plots chromatograms and prints data. Data can also be reported to an external computer, which is connected through an RS-232 outlet. Either photoionization or electron-capture detectors can be used. Capillary columns of all sizes can be installed. The unit is capable of autosampling.

WASTE APPLICABILITY:

The HNU GC 311 portable isothermal gas chromatograph is potentially applicable to a wide variety of vapor phase pollutants, but its field performance is still under evaluation. The photoionization detector is sensitive to compounds that ionize below 10.4 electron volts, such as aromatic compounds and unsaturated halocarbons. The electron-capture detector is sensitive to compounds with a high affinity for electrons, such as halocarbons.



HNU GC 311

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

The instrument was evaluated at a Superfund site under remediation in January 1992. Results from the demonstration are presented in a peer-reviewed article entitled "Evaluation of Portable Gas Chromatograph" in the *Proceedings of the 1993 U.S. EPA/Air and Waste Management Association International Symposium*, VIP-33, Vol. 2, 1993. A final report will not be prepared.

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The SITE Program assesses but does not approve or endorse technologies.

IDETEK, INC.
(formerly BINAX CORPORATION, ANTOX DIVISION)
(Equate® Immunoassay)

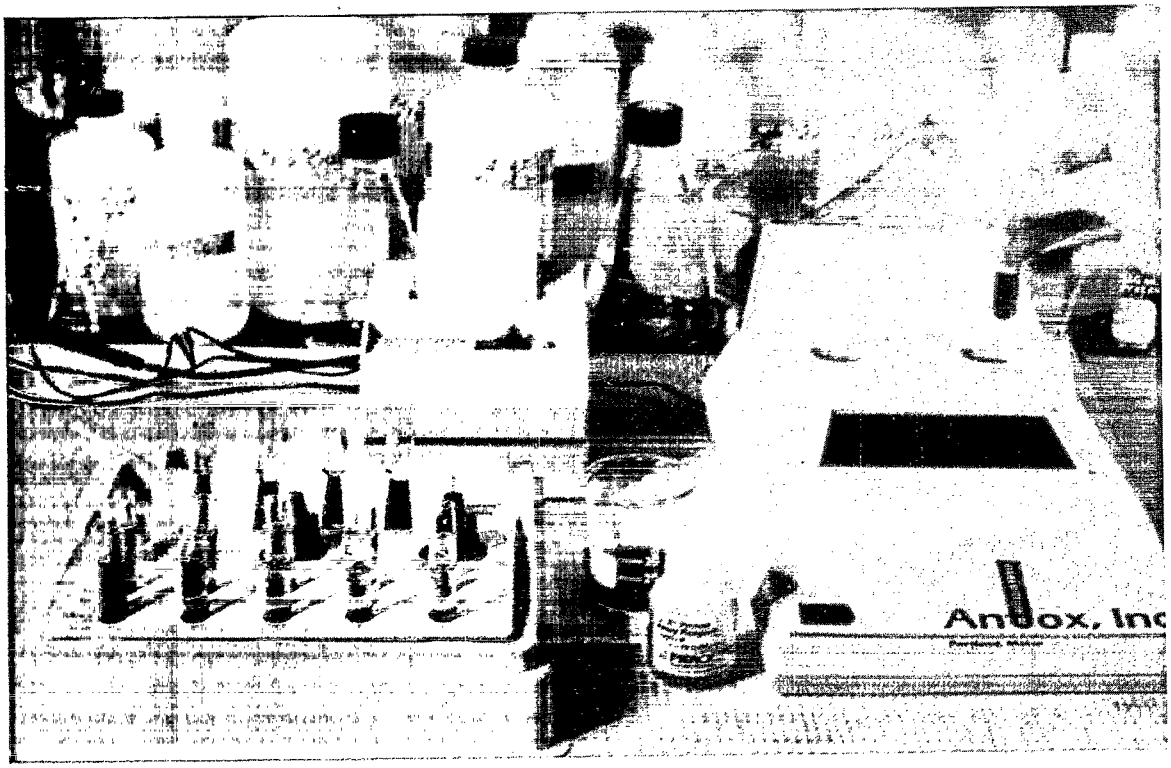
TECHNOLOGY DESCRIPTION:

The Equate® immunoassay uses an anti-benzene, toluene, and xylene (BTX) polyclonal antibody to facilitate analysis of BTX in water. A hapten-enzyme conjugate mimics free BTX hydrocarbons and competes for binding to the polyclonal antibody immobilized on a test tube. After washing to remove unbound conjugate, a substrate chromogen mixture is added and a colored enzymatic reaction product is formed. The enzymatic reaction is stopped by adding a few drops of sulfuric acid, which changes the color to yellow.

As with other competitive enzyme-linked immunosorbent assays, the color intensity of the enzymatic product is inversely proportional to the sample analyte concentration. Each sample is run with a reference sample of deionized water. The optical density of the colored enzymatic product is read on a portable digital colorimeter equipped with a filter that passes light at a peak wavelength of 450 nanometers. The ratio of the sample to the reference optical density values is used to estimate the aromatic hydrocarbon level in the low parts per million (ppm) range. The test is sensitive to about 1 ppm and requires 5 to 10 minutes per analysis.

WASTE APPLICABILITY:

The immunoassay is designed to measure aromatic hydrocarbons in water.



Equate® Immunoassay Kit

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

The Environmental Monitoring System Laboratory–Las Vegas evaluated several successful versions of the immunoassay. The evaluation focused on cross–reactivity and interference testing and on analysis of benzene, toluene, ethylbenzene, and xylene (BTEX) and gasoline standard curves.

As a preliminary field evaluation, five well samples and a creek sample were analyzed in duplicate, both in the field and the laboratory, by the immunoassay. For confirmation, samples were also analyzed by purge–and–trap gas chromatography with an electron capture detector, in parallel with a photoionization detector.

A SITE demonstration of the Equate® immunoassay was conducted in 1992. Results from this demonstration were published in June 1994 in an EPA report entitled "Superfund Innovative Technology Evaluation (SITE) Program Evaluation Report for Antox BTX Water Screen (BTX Immunoassay)," (EPA540/R-93/518).

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The SITE Program assesses but does not approve or endorse technologies.

MDA SCIENTIFIC, INC.
(Fourier Transform Infrared Spectrometer)

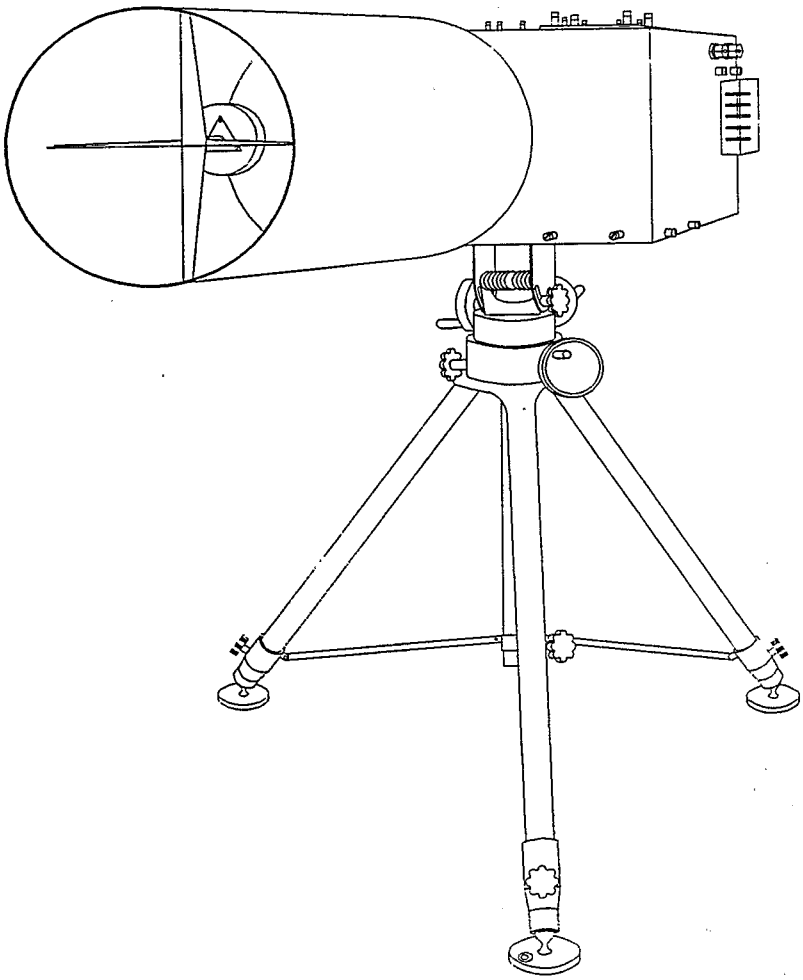
TECHNOLOGY DESCRIPTION:

The field-deployable, long-path Fourier transform infrared spectrometer measures infrared absorption by infrared-active molecules (see photograph below). An infrared beam is transmitted along a path to a retroflector, which returns the beam to the detector. The total path can be up to 1 kilometer long. The system does not need calibration in the field.

Results are analyzed with a reference spectrum of known concentration and classical least squares fitting routines. The spectrometer does not need a sample, thereby ensuring sample integrity. A measurement requires only a few minutes, which allows determination of temporal profiles for pollutant gas concentrations.

WASTE APPLICABILITY:

The Fourier transform infrared spectrometer can measure various airborne vapors, including both organic and inorganic compounds, especially those that are too volatile to be collected by preconcentration methods. The spectrometer can



Fourier Transform Infrared Spectrometer

The SITE Program assesses but does not approve or endorse technologies.

monitor emissions from hazardous waste sites during remediation. Under proper conditions, it may be possible to estimate vapor emission rates from the site.

STATUS:

The Fourier transform infrared spectrometer has been evaluated in several field studies and has proven capable of detecting various significant airborne atmospheric vapors. Software that identifies and quantifies compounds in the presence of background interference is under development. Field-operating procedures and quality control procedures are being established. This instrument was evaluated at a Superfund site in January 1992. Results from this field evaluation are published in an EPA report entitled "Superfund Innovative Technology Evaluation, The Delaware SITE Study, 1989" (EPA/600/A3-91/071).

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The SITE Program assesses but does not approve or endorse technologies.

MICROSENSOR SYSTEMS, INCORPORATED
(Portable Gas Chromatograph)

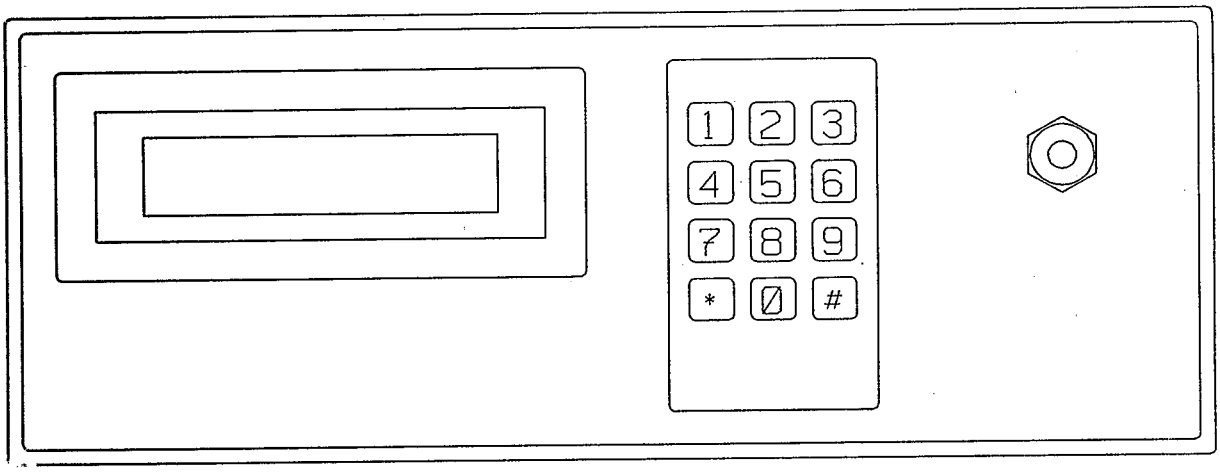
TECHNOLOGY DESCRIPTION:

The MSI-301A vapor monitor is a portable, temperature-controlled gas chromatograph with a highly selective surface acoustic wave detector and an on-board computer (see figure below). The MSI-301A vapor monitor performs the following functions:

- Preconcentrates samples and uses scrubbed ambient air as a carrier gas.
- Analyzes a limited group of preselected compounds, such as benzene, toluene, and xylenes, at part-per-billion levels.
- Operates by battery and includes an RS-232 interface.
- Operates automatically as a stationary sampler or manually as a mobile unit.

WASTE APPLICABILITY:

The MSI-301A vapor monitor can monitor volatile organic compound emissions from hazardous waste sites and other sources before and during remediation. It can be applied to many kinds of vapor phase pollutants, but its performance characteristics in the field have not been evaluated.



MSI-301A Vapor Monitor

The SITE Program assesses but does not approve or endorse technologies.

STATUS:

In January 1992, the MSI-301A vapor monitor was evaluated in the field at a Superfund site. Results from the demonstration are presented in a peer-reviewed article entitled "Evaluation of Portable Gas Chromatographs" in the *Proceedings of the 1993 U.S. EPA/Air and Waste Management Association International Symposium*, VIP-33, Vol. 2, 1993.

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The SITE Program assesses but does not approve or endorse technologies.

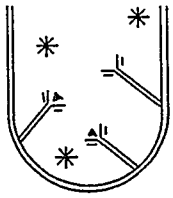
MILLIPORE CORPORATION
(EnviroGard™ PCB Immunoassay Test Kit)

TECHNOLOGY DESCRIPTION:

The EnviroGard™ polychlorinated biphenyl (PCB) immunoassay test kit rapidly analyzes for PCB concentrations in soils. The test kit procedure is shown in the figure below.

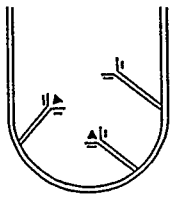
Soil sample extracts are added to test tubes coated with antibodies that bind PCB molecules. The soil extracts are washed away after incubation, and the PCB conjugate, a horse radish peroxidase enzyme, mimics free PCB molecules and is added to the tubes. Unoccupied antibody binding sites bind the PCB conjugate. Excess PCB conjugate is washed away. An enzyme substrate and a coloring agent are then added to the test tube.

Incubation 1:
Dilution of sample or calibrator is incubated in tube containing immobilized antibodies.

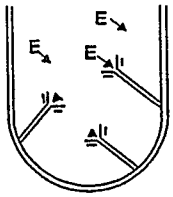


▲ = PCB
✳ = Non-PCB Material in Filtrate or Calibrator
= PCB Antibody

Wash 1:
Non-PCB material is washed away, leaving only PCBs bound to antibodies.

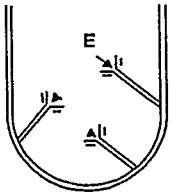


Incubation 2:
PCB-HRP binds to free anti-PCB sites on immobilized antibodies.

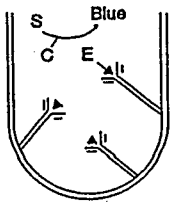


E = HRP (Horse Radish Peroxidase Enzyme)

Wash 2:
Unbound PCB-HRP is washed away, leaving an amount of enzyme inversely proportional to the PCB concentration in incubation 1.



Incubation 3:
Colorless substrate and chromogen become blue in proportion to amount of bound enzyme. Less color means more PCB Stop solution inactivates the HRP, changes color to yellow, and stabilizes color.



S = Substrate
C = Chromogen

Test Kit Procedure

The SITE Program assesses but does not approve or endorse technologies.

The color intensity in the test tube is measured at 405 nanometers using a small, portable spectrophotometer. The color intensity is inversely proportional to PCB concentration in the soil sample. The results obtained from the soil samples are compared against three calibrators of 5, 10, and 50 parts per million (ppm). This type of test is called a competitive enzyme-linked immunosorbent assay (ELISA).

PCB concentrations are semiquantitatively classified as below 5 ppm, between 5 and 10 ppm, between 10 and 50 ppm, and greater than 50 ppm. Up to six sample analyses (in duplicate) can be performed in about 15 to 20 minutes. Millipore Corporation can provide optional protocols to perform more detailed quantitative analysis.

WASTE APPLICABILITY:

The PCB immunoassay test kit measures PCB concentrations in soil. The test is sensitive equally to Aroclors 1016, 1232, 1242, 1248, 1254, and 1260, with moderate sensitivity to Aroclor 1221. Test detection limits are reported to be 0.1 part per billion in water and 0.1 ppm in soils. Millipore has also developed ELISA kits under the EnviroGard™ trademark for triazine, aldicarb, 2,4-dichlorophenoxyacetic acid (2,4-D), carbofuran, pentachlorophenol, cyclodienes, alachlor, and benomyl. These kits have been used to test for contaminants in food, water, soil, and contaminated surfaces, and are available for commercial distribution.

STATUS:

The EnviroGard™ PCB immunoassay test kit has been used to screen and quantify PCB contamination in soils at a SITE demonstration of a solvent extraction system in Washburn, Maine. The kit was also demonstrated at a U.S. Department of Energy (DOE) site in Kansas City, Missouri.

Soil containing over 50 ppm PCB was required for the demonstration tests at the Washburn, Maine site. Calibrators at the 5 and 50 ppm level were used to evaluate the kit's potential for segregating soils. Additional tests were performed on dilutions of the soil extracts to evaluate quantitative performance. Highly contaminated soils were easily identified, and quantitative tests provided correlation to contaminant levels obtained by off-site laboratory analysis using EPA Method 8080.

Soils contaminated with Aroclor 1242 in ranges from non-detectable to greater than 1,000 ppm were analyzed with the test kit at the DOE facility. Over 200 assays of environmental samples and calibrators were performed to evaluate correlation with both on-site and off-site laboratory gas chromatograph data. Final evaluation of the data will be presented in the Technology Evaluation Report.

Draft methods for the PCB test in soil were submitted for review by the Office of Solid Waste methods panel in summer 1992. The final report is undergoing peer review and will be published in 1995.

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The SITE Program assesses but does not approve or endorse technologies.

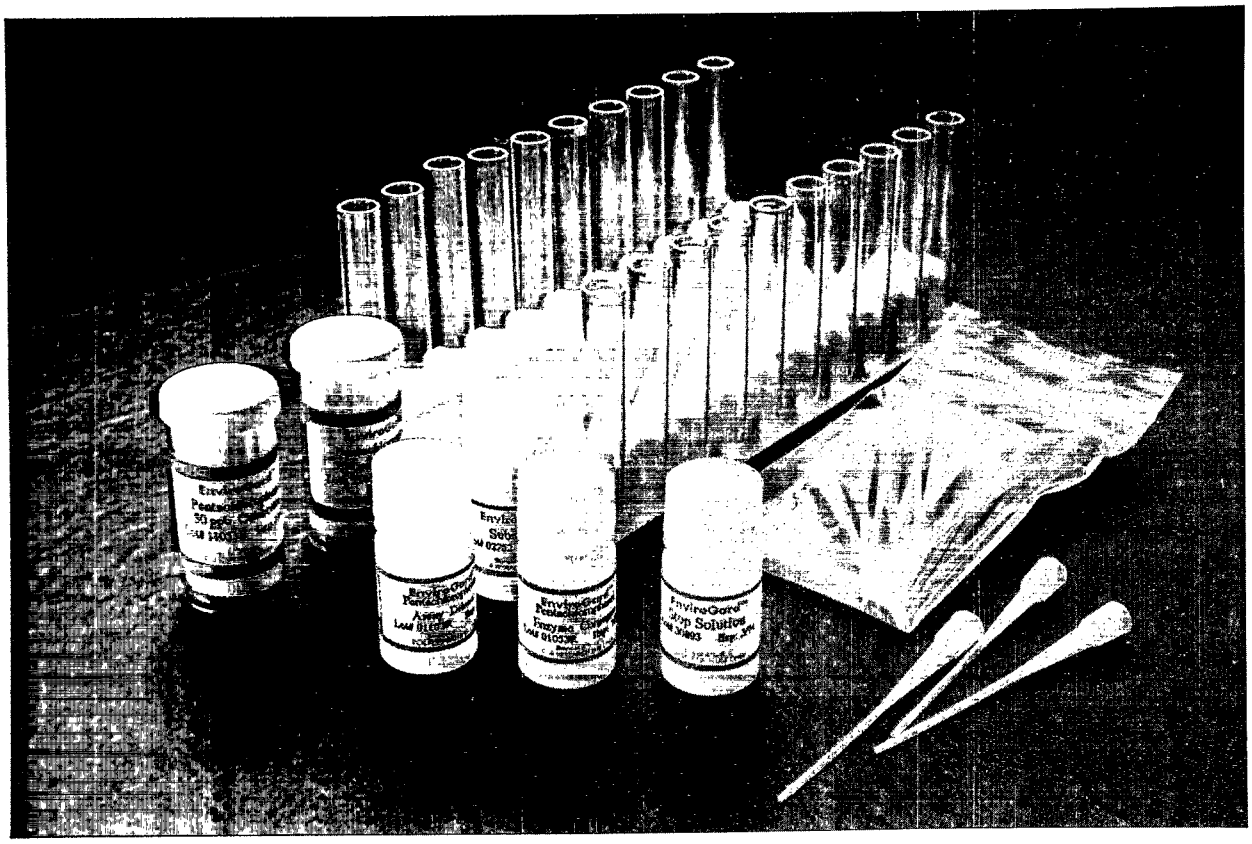
MILLIPORE CORPORATION
(EnviroGard™ PCP Immunoassay Test Kit)

TECHNOLOGY DESCRIPTION:

The EnviroGard™ pentachlorophenol (PCP) test can provide rapid semiquantitative and quantitative results at sites where the soil and water are contaminated by PCP. The procedure is performed by adding a water or soil sample extract to test tubes and introducing an enzyme conjugate. The PCPs from the sample and the enzyme conjugate compete for immobilized anti-pentachlorophenol antibody binding sites. The antibodies then bind to the walls of the test tubes.

The reaction of the enzyme conjugate with added colorization reagents yields the results. A small, portable spectrophotometer measures the color intensity, which is inversely proportional to PCP concentrations in the sample. The results are compared against three calibration standards: 25 parts per billion (ppb), 250 ppb, and 5,000 ppb. This type of test is called competitive enzyme-linked immunosorbent assay (ELISA).

PCP concentrations can be semiquantitatively classified for soil samples as follows: below 25 ppb; between 25 and 250 ppb; between 250 and 5,000 ppb; and greater than 5,000 ppb. The PCP concentrations in water can be classified as follows: below 5 ppb; between 5 and 20 ppb; between 20 and 100 ppb; and greater than 100 ppb. Different detection levels are achieved by



EnviroGard™ PCP Immunoassay Test Kit

The SITE Program assesses but does not approve or endorse technologies.

diluting the water sample or the solid sample extract.

The test kit can be affected by naturally occurring matrix effects such as humic acids, pH, or salinity. Site-specific matrix effects that can affect the kits include: PCP carriers, such as petroleum hydrocarbons or solvents; and other chemicals used in conjunction with PCP, including creosote, copper-chromium-arsenate, or herbicides. Specific chemicals similar in structure to PCP can provide false positive results, or chemical cross reactivity.

WASTE APPLICABILITY:

The PCP immunoassay measures PCPs in soil and water samples. Detection limits are 25 ppb for soil and 5.0 ppb for water samples. Millipore has also developed ELISA kits under the EnviroGard™ trademark for triazine, aldicarb, 2,4-dichlorophenoxyacetic acid (2,4-D), carbofuran, cyclodienes, polychlorinated biphenyls, alachlor, and benomyl. These kits have been used to test for contaminants in food, water, soil, and contaminated surfaces and are available for commercial distribution.

STATUS:

The EnviroGard™ PCP Immunoassay test kit was used to screen and quantify PCP contamination in soil and groundwater during a SITE demonstration in Morrisville, North Carolina in August 1993. The PCP carrier used at this site was a mixture of isopropyl ether and butane. In addition, soil and groundwater samples collected from Winona, Missouri, were tested during the demonstration. These samples had a PCP diesel fuel carrier.

The test kit did not meet acceptable accuracy requirements during the demonstration; it did not meet Level 1 criteria. Millipore recognized the need to improve the PCP test kit and has since developed a revised protocol for PCP analysis. Millipore believes the revisions will improve the accuracy and reproducibility of the test.

The draft of the Technology Evaluation Report for the PCP was submitted to EPA in spring 1994. The draft of the report is undergoing peer review and will be released in the final form at a later date.

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The SITE Program assesses but does not approve or endorse technologies.

MTI ANALYTICAL INSTRUMENTS
(formerly MICROSENSOR TECHNOLOGY, INCORPORATED)
(Portable Gas Chromatograph)

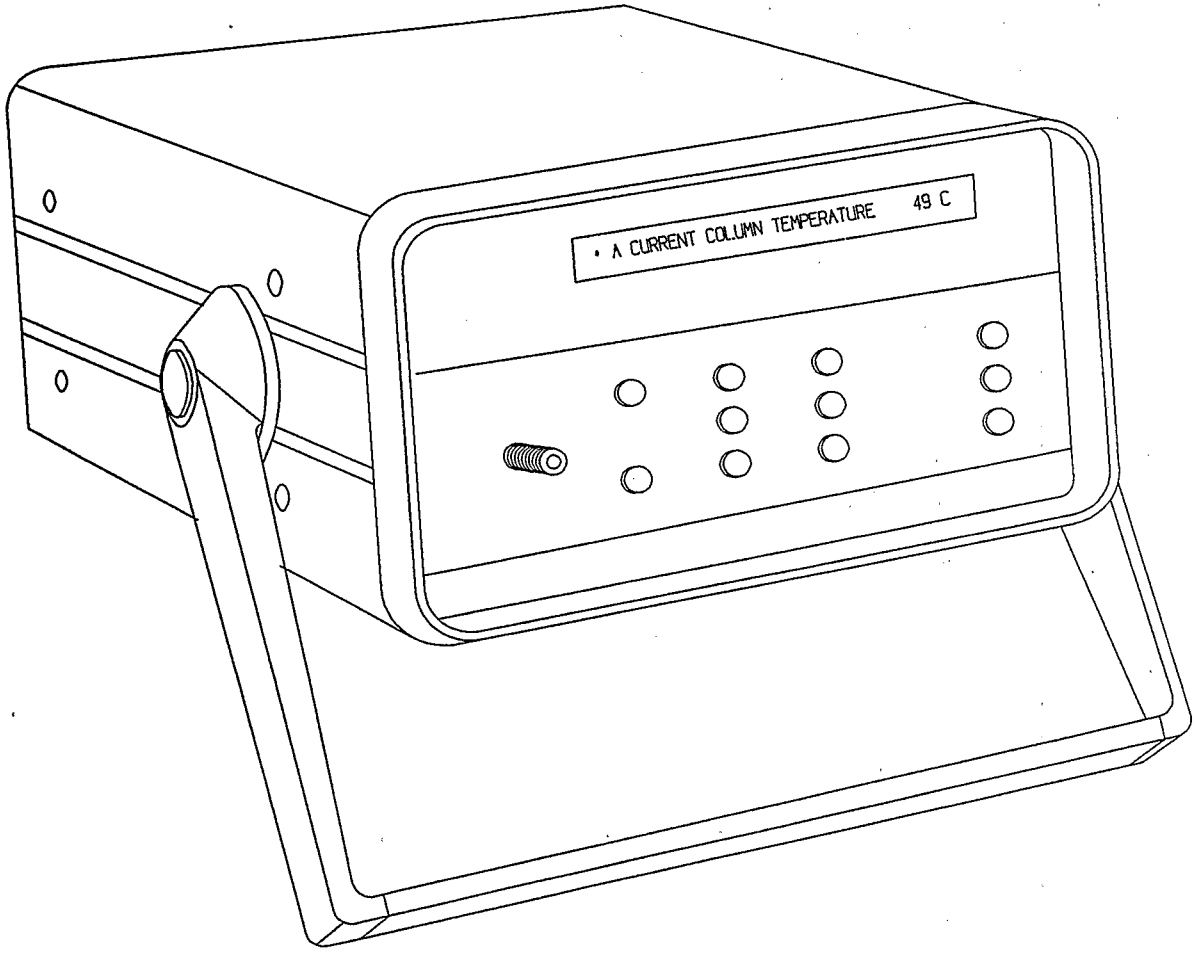
TECHNOLOGY DESCRIPTION:

The MTI Analytical Instruments M200 gas analyzer is a dual-channel portable isothermal gas chromatograph (see figure below). The injection system and thermal conductivity detector are micromachined in silicon and connected by a short length of microbore column. Samples are drawn through a sample loop with a vacuum pump and placed in line with the carrier stream.

The M200 gas analyzer can detect concentrations as low as 1 part per million (ppm) for a wide variety of volatile organic compounds (VOC), without preconcentration. Chromatograms are completed in less than 5 minutes. Analysis of concentrations below 1 ppm requires a preconcentrator.

WASTE APPLICABILITY:

The M200 gas analyzer can potentially monitor VOC emissions from hazardous waste sites before and during remediation. Because of the universal sensitivity of its thermal conductivity detector, the M200 gas analyzer is potentially



M200 Gas Analyzer

The SITE Program assesses but does not approve or endorse technologies.

applicable to many types of vapor phase compounds, both organic and inorganic. However, its performance characteristics in field operation have not been evaluated because a suitable preconcentrator is unavailable.

STATUS:

The M200 gas analyzer was evaluated in the laboratory from 1990 to 1992. Without preconcentration, the instrument's sensitivity was inadequate for field operation.

FOR FURTHER INFORMATION:

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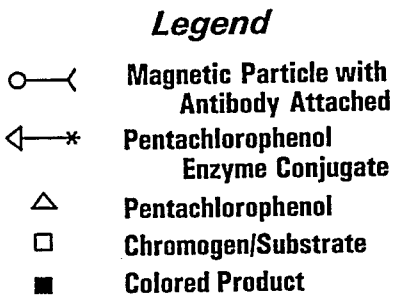
The SITE Program assesses but does not approve or endorse technologies.

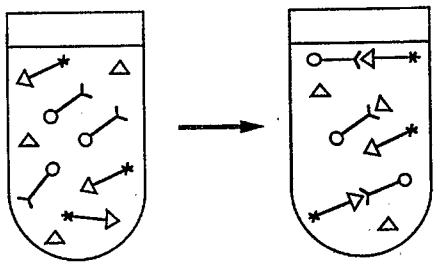
OHMICRON CORPORATION
(Pentachlorophenol RaPID Assay)

TECHNOLOGY DESCRIPTION:

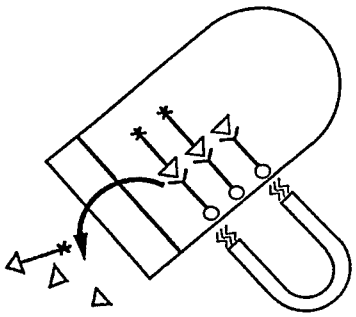
The RaPID Assay kit is designed to quickly provide quantitative results for pentachlorophenol (PCP) concentrations in soil and water samples. The kit uses immunoassay chemistry to produce detectable and quantifiable compound-specific reactions for PCP. Polyclonal antibodies bind to paramagnetic particles and are introduced into a test tube where they offer binding sites for PCP. An enzyme conjugate containing a PCP derivative is added to the test tube, where it competes with PCP from samples for antibody binding sites. A magnetic field is applied to each test tube to hold the paramagnetic particles containing PCP and enzyme conjugate, while excess sample and enzyme conjugate are washed from the test tube. Reagents are then added to the test tube, where they react with the enzyme conjugate and form a color. The color formed in the sample is compared to the color formed by PCP calibration standards. The comparison is made with a spectrophotometer. Samples with PCP concentrations above the calibration range can be diluted and reanalyzed.

The RaPID Assay kit has several advantages and limitations when used under field conditions. The method is field portable, easy and fast to operate, and inexpensive. The RaPID Assay kit is limited in that electricity is required to operate the spectrophotometer, the immunoassay method may be affected by temperature fluctuations, and cross-reactivity potential exist for compounds similar to PCP.

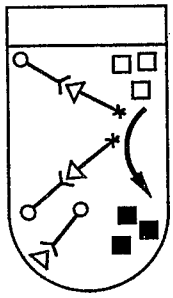




1. Immunological Reaction



2. Separation



3. Color Development

Ohmicron RaPID Assay®

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The RaPID Assay kit can be used to identify and quantify PCPs in soil and water samples. Ohmicron Corporation reports the detection limit for soils at 0.1 parts per million and water samples at 0.06 parts per billion.

STATUS:

The RaPID Assay kit was evaluated during a SITE field demonstration in Morrisville, North Carolina in August 1993. In addition, samples collected from a location in Winona, Missouri were analyzed to evaluate the effects of different matrices and PCP carriers.

The draft of the Technology Evaluation Report for the PCP test was submitted EPA in spring 1994. The draft of the report is undergoing peer review and will be released in final report form at a later date.

FOR FURTHER INFORMATION:

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RaPID Assay Used During the SITE Demonstration

OUTOKUMPU ELECTRONICS, INC.
(Metorex X-MET 920P XRF Analyzer)

TECHNOLOGY DESCRIPTION:

The Metorex X-MET 920P X-ray fluorescence (XRF) analyzer is built to withstand the rigors of the field. It can simultaneously analyze 32 inorganic elements ranging from aluminum to uranium. The X-MET 920P XRF analyzer is compact and lightweight. It requires liquid nitrogen for detector operation; but once filled can operate for over 8 hours with one fill. A rechargeable battery allows the XRF unit to be used at remote sites where electricity is not available.

The X-MET 920P XRF analyzer uses a silicon-lithium detector to provide high elemental

Outokumpu Metorex X-MET 920P XRF Analyzer

The SITE Program assesses but does not approve or endorse technologies.

resolution and low detection limits. Four radioisotope excitation sources provide a broad range of excitation energies to identify and quantify inorganic elements.

The X-MET 920P XRF analyzer provides high sample throughput, and it is reportedly easy to operate. Analytical results obtained by this instrument are reportedly comparable to results obtained by EPA-approved methods.

WASTE APPLICABILITY:

The X-MET 920P XRF analyzer can be used to detect inorganic elements in solids, liquids, slurries, powders, and films, which includes air particulates on filters. The analyzer can identify inorganic elements at concentrations ranging from parts per million to percentage levels.

STATUS:

The X-MET 920P XRF analyzer has been used at a number of Superfund sites across the country. A SITE demonstration of the X-MET 920P XRF analyzer is scheduled for February 1995.

FOR FURTHER INFORMATION:

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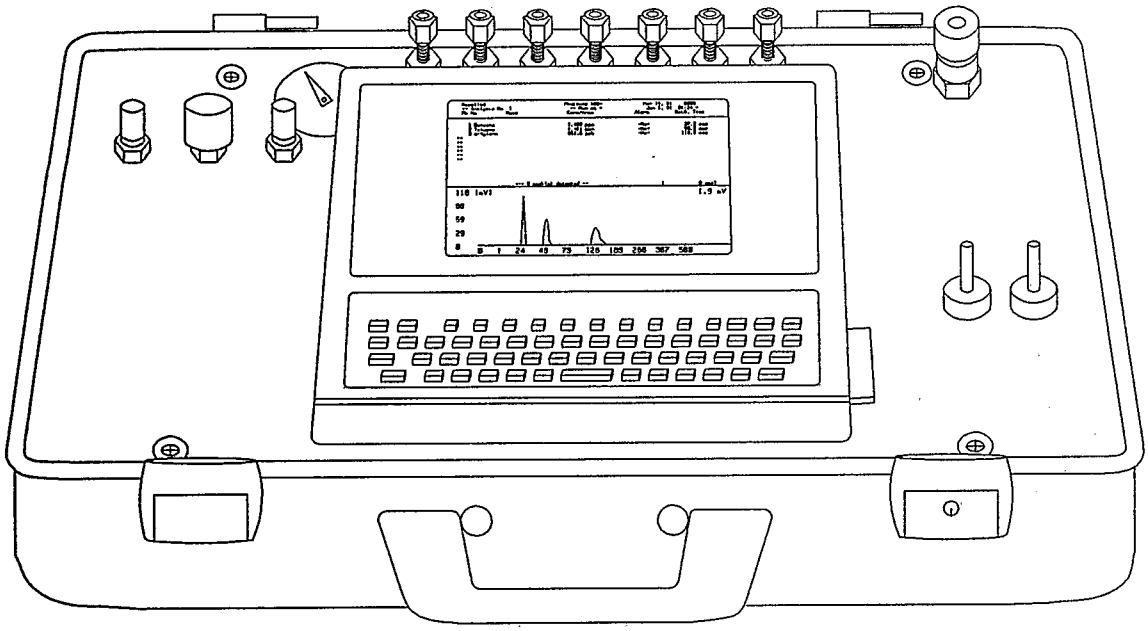
The SITE Program assesses but does not approve or endorse technologies.

PHOTOVAC INTERNATIONAL, INC.
(Photovac 10S PLUS)

TECHNOLOGY DESCRIPTION:

The Photovac 10S PLUS is a redesigned version of the Photovac 10S70, a battery-powered portable isothermal gas chromatograph (see figure below). The 10S PLUS addresses the following 10S70 design problems:

- All-steel valves significantly reduce memory effect and carryover contamination.
- Autoranging permits operation at high gain.
- An on-board computer controls the unit and manages data.
- The 10.6-electron-volt (eV) photoionization detector is limited to low temperature operation.
- The 10S PLUS is more sensitive and highly selective for a limited number of compounds that ionize below 10.6 eV and are volatile enough to elute at 50 degrees Celsius or below.
- This unit is capable of detecting benzene, toluene, xylenes, and chlorinated ethylenes in preconcentration samples that are small enough to be chromatographed at concentrations well below 1 part per billion.



Photovac 10S PLUS

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The Photovac 10S PLUS can monitor volatile organic compound emissions from hazardous waste sites and other emission sources before and during remediation. The 10S PLUS is more effective than the 10S70 for monitoring volatile aromatic and chlorinated olefin compounds at ambient background levels.

STATUS:

The Photovac 10S PLUS was evaluated at a Superfund site under remediation in January 1992. Results from this demonstration are presented in a peer-reviewed article entitled "Evaluation of Portable Gas Chromatographs" in the *Proceedings of the 1993 U.S. EPA/Air and Waste Management Association International Symposium*, VIP-33, Vol. 2, 1993.

FOR FURTHER INFORMATION:

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The SITE Program assesses but does not approve or endorse technologies.

SCITEC CORPORATION
(Metal Analysis Probe [MAP®] Portable Assayer]

TECHNOLOGY DESCRIPTION:

The SCITEC Metal Analysis Probe (MAP®) Portable Assayer is a field portable X-ray fluorescence (XRF) analyzer. This XRF analyzer can simultaneously analyze inorganic elements. It is compact, lightweight, and does not require liquid nitrogen. A rechargeable battery allows the XRF analyzer to be used at remote sites where electricity is not available.

The MAP® Portable Assayer uses a silicon X-ray detector to provide high elemental resolution and low detection limits. Three radioisotope excitation sources provide a broad range of excitation energies to identify and quantify inorganic elements.

The MAP® Portable Assayer provides high sample throughput and is reportedly easy to operate. Analytical results obtained by this

MAP® Portable Assayer

The SITE Program assesses but does not approve or endorse technologies.

instrument are reportedly comparable to the results obtained by EPA-approved methods.

WASTE APPLICABILITY:

The MAP® Portable Assayer can detect inorganic elements in soil and sediment samples and filter and wipe samples, and can detect lead in paint. The MAP® Portable Assayer can identify inorganic elements at concentrations ranging from parts per million to percentage levels.

STATUS:

The MAP® Portable Assayer has been used at a number of Superfund sites across the country. A SITE demonstration of the MAP® Portable Assayer is scheduled for February 1995.

FOR FURTHER INFORMATION:

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The SITE Program assesses but does not approve or endorse technologies.

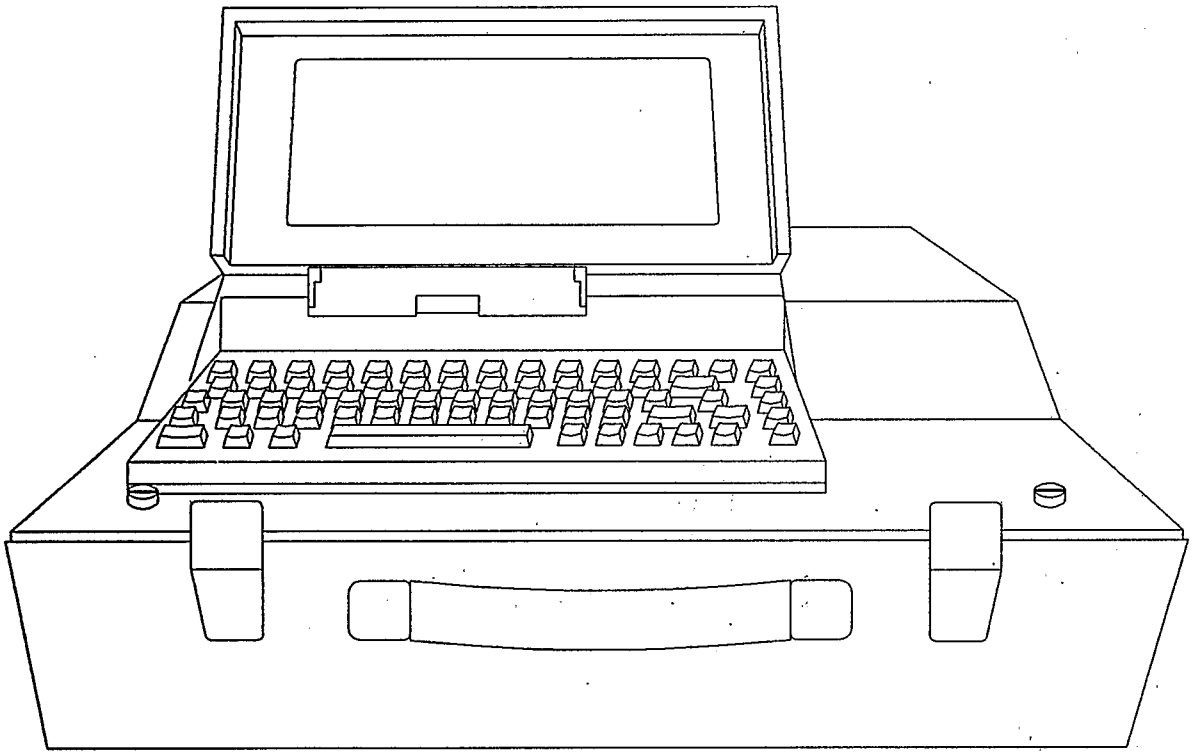
SENTEX SENSING TECHNOLOGY, INC.
(Scentograph Portable Gas Chromatograph)

TECHNOLOGY DESCRIPTION:

The Scentograph Portable Gas Chromatograph can operate for several hours on internal batteries and has internal carrier gas and calibrant tanks (see figure below). It can be fitted with a megabore capillary column or a packed column. The instrument can be operated isothermally at elevated temperatures or ballistically temperature-programmed. The portable gas chromatograph operates by drawing air through a sorbent bed, followed by rapid thermal desorption into the carrier stream. The chromatograph may operate in either argon ionization or electron-capture modes. The 11.7-electron-volt ioniza-tion energy makes the chromatograph nearly universal, with a detection limit of about 1 part per billion. The instrument is controlled by an attached IBM PC/XT compatible laptop computer.

WASTE APPLICABILITY:

The scentograph portable gas chromatograph can monitor volatile organic compound emissions from hazardous waste sites and other emission



Portable Gas Chromatograph

The SITE Program assesses but does not approve or endorse technologies.

sources before and during remediation. It has been used for several years in water and soil analyses and can analyze all types of vapor phase pollutants.

STATUS:

The Scentograph Portable Gas Chromatograph was evaluated in January 1992 at a Superfund Site under remediation. Results from this demonstration are presented in a peer-reviewed article entitled "Evaluation of Portable Gas Chromatographs" in the *Proceedings of the 1993 U.S. EPA/Air and Waste Management Association International Symposium*, VIP-33, Vol. 2, 1993.

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The SITE Program assesses but does not approve or endorse technologies.

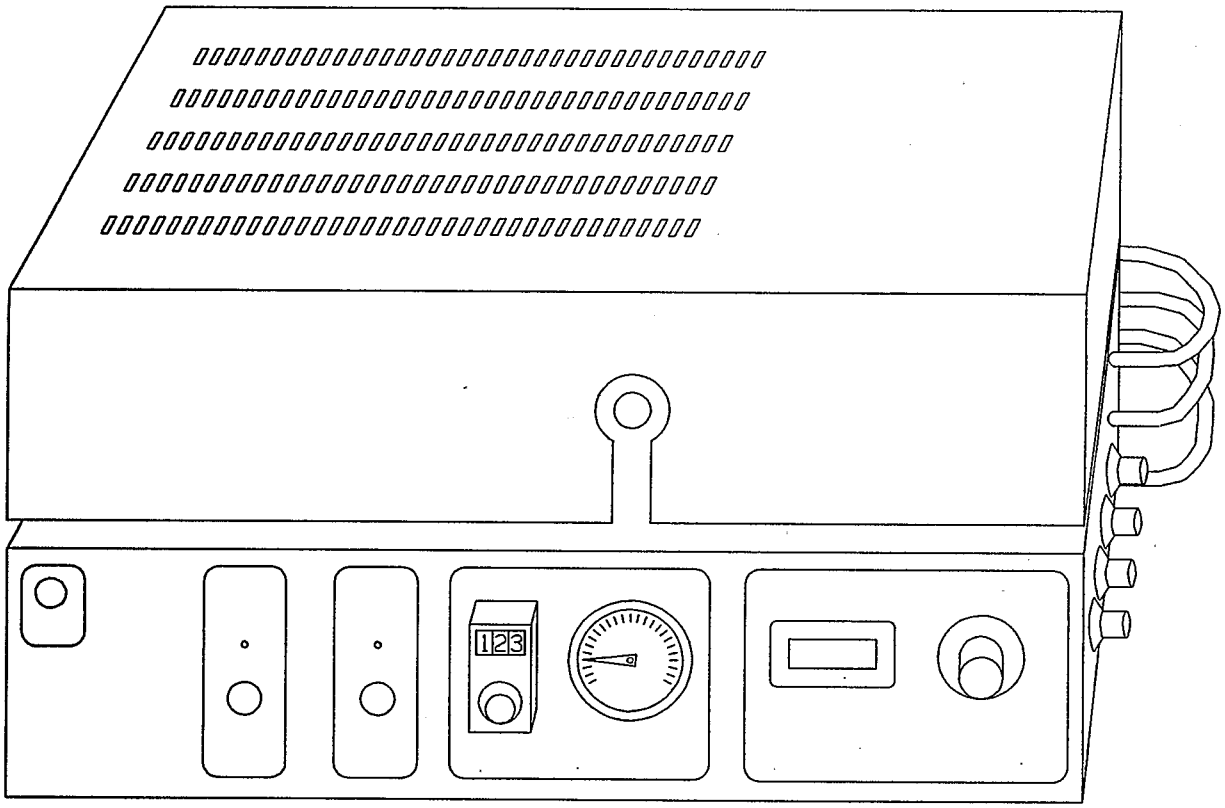
SRI INSTRUMENTS
(Gas Chromatograph)

TECHNOLOGY DESCRIPTION:

The SRI Instruments (SRI) 8610 gas chromatograph is a small, low-cost laboratory instrument that is field-deployable (see figure below). It is temperature-programmable and features a built-in purge-and-trap system. The column oven is designed to fit all standard packed and capillary columns. Thermal conductivity, flame ionization, nitrogen-phosphorus, thermionic ionization, photoionization, electron capture, Hall, and flame photometric detectors can be used. Up to three detectors may be simultaneously mounted in series.

WASTE APPLICABILITY:

The SRI 8610 gas chromatograph can monitor airborne emissions from hazardous waste sites and other emission sources before and during



8610 Gas Chromatograph

The SITE Program assesses but does not approve or endorse technologies.

remediation. It can be applied to volatile organic compounds, but its performance characteristics in the field have not been evaluated.

STATUS:

The SRI 8610 gas chromatograph was evaluated in January 1992 at a Superfund Site under remediation. Results from this demonstration are presented in a peer-reviewed article entitled "Evaluation of Portable Gas Chromatographs" in the *Proceedings of the 1993 U.S. EPA/Air and Waste Management Association International Symposium*, VIP-33, Vol. 2, 1993.

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The SITE Program assesses but does not approve or endorse technologies.

TN TECHNOLOGIES, INC.
(Spectrace 9000 X-Ray Fluorescence Analyzer)

TECHNOLOGY DESCRIPTION:

The Spectrace 9000 X-ray fluorescence (XRF) analyzer is a field portable unit capable of simultaneously analyzing inorganic elements, from sulfur to uranium. It is compact, lightweight, and does not require liquid nitrogen. A rechargeable battery allows the XRF unit to be used at remote sites where electricity is not available.

The Spectrace 9000 XRF analyzer uses a high resolution mercuric iodide detector to provide high elemental resolution and low detection limits. Three radioisotope excitation sources provide a broad range of excitation energies for identifying and quantifying 26 elements.

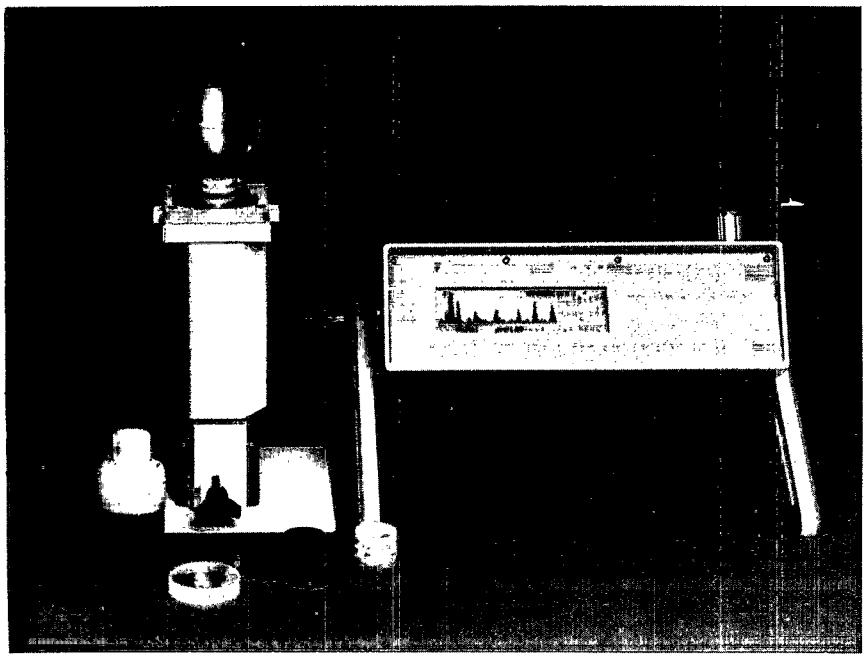
The Spectrace 9000 XRF analyzer provides high sample throughput and is reportedly easy to operate. It can be used to achieve Quality Assurance (QA) Level 1 and QA Level 2 data quality objectives, and reportedly correlates well with EPA-approved methods.

WASTE APPLICABILITY:

The Spectrace 9000 XRF analyzer can detect inorganic elements in soil and sediment samples and filter and wipe samples, and can detect lead in paint. The XRF analyzer can identify inorganic elements at concentrations ranging from parts per million to percentage levels.

STATUS:

The Spectrace 9000 XRF analyzer has been used at a number of Superfund sites across the country. A SITE demonstration of the Spectrace XRF unit is scheduled for February 1995.



TN Technologies Spectrace 9000 X-Ray Fluorescence Analyzer

The SITE Program assesses but does not approve or endorse technologies.

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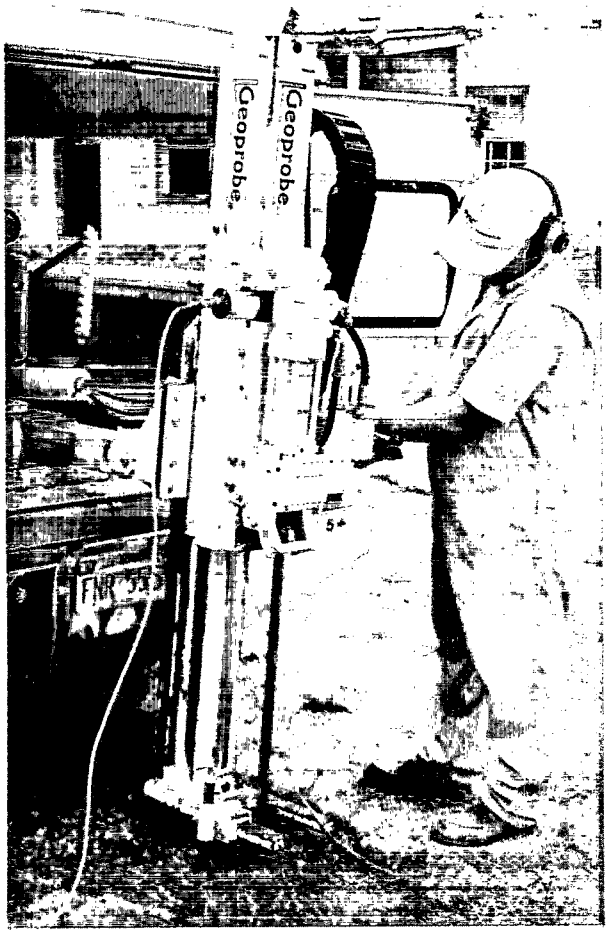
The SITE Program assesses but does not approve or endorse technologies.

TRI-SERVICES
(Site Characterization Analysis Penetrometer System [SCAPS])

TECHNOLOGY DESCRIPTION:

The Tri-Services Site Characterization Analysis Penetrometer System (SCAPS) was developed by the U.S. Army (U.S. Army Corps of Engineers, Waterways Experiment Station [WES] and the Army Environmental Center [AEC]), Navy (Naval Command, Control and Ocean Surveillance Center), and the Air Force (Armstrong Laboratory). The U.S. Army holds a patent for this application of laser sensors combined with cone penetrometry. The laser induced fluorescence (LIF) system used in the SCAPS system was modified from a design developed by the Navy to detect petroleum, oil, and lubricant fluorescence in seawater.



Tri-Services SCAPS

A complete cone penetrometer truck (CPT) system consists of a truck, hydraulic rams and associated controllers, and the CPT itself. The weight of the truck provides a static reaction force, typically 20 tons, to advance the cone penetrometer. The hydraulic system, working against the static reaction on force, advances 1-meter-long segments of 3.57-centimeter-diameter threaded push rod into the ground. The CPT, which is mounted on the end of the series of push rods, contains sensors that continuously log tip stress and sleeve friction. The data from these sensors is used to map subsurface stratigraphy. Conductivity or pore pressure sensors can be driven into the ground simultaneously.

The core of the SCAPS LIF system is the penetrometer unit mounted on a specially engineered 20-ton truck designed with protected work spaces. The SCAPS system has been modified to provide automatic grouting of the penetrometer hole during retraction of the cone penetrometer, and also decontaminates the push rods as they are retracted from the soil. The 20-ton CPT is capable of pushing standard push rods to depths of approximately 50 meters.

The main LIF sensor components are:

- Nitrogen (N_2) laser
- Fiber optic cable
- Monochromator to resolve the fluorescence emission as a function of wavelength
- Photodiode array (PDA) to detect the fluorescence emission spectrum and transduce the optical signal into an electrical signal
- OMA to interface between the optic system and the computer system
- Computer system

The SITE Program assesses but does not approve or endorse technologies.

To operate the SCAPS LIF sensor, the CPT is positioned over a designated penetration point. The LIF sensor response is checked using a standard rhodamine solution held against the sapphire window; sensor response is checked before and after each penetration. The cone penetrometer is then advanced into the soil.

The SCAPS LIF system is operated with a N_2 laser. The PDA accumulates the fluorescence emission response over 10 laser shots, and the PDA retrieves an emission spectrum of the soil fluorescence and returns this information to the OMA and computer system. The LIF sensor and stratigraphy data collection are interpreted by the on board computer system.

The spectral resolution of the LIF system under these operating conditions is 2 cm. The fluorescence intensity at peak emission wave-length for each stored spectrum is displayed along with the soil classification data.

WASTE APPLICABILITY:

The Tri-Services SCAPS was designed to qualitatively and quantitatively identify classes of petroleum, polynuclear aromatic hydrocarbons, and volatile organic compound contamination in subsurface soil samples.

STATUS:

The technology field demonstration was held in EPA Region 7 during September 1994. After completing the demonstration, a Technology Evaluation Report (TER) will be prepared. The TER will present the results of the demonstration objectively and provide supporting documentation. In addition, an Innovative Technology Evaluation Report (ITER) will be prepared and published that summarizes the findings presented in the TER. These reports will help data users and technology reviewers assess the performance of each technology for possible use on future site characterization or remediation projects at hazardous waste sites.

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The SITE Program assesses but does not approve or endorse technologies.

UNISYS CORPORATION
(Rapid Optical Screen Tool)

TECHNOLOGY DESCRIPTION:

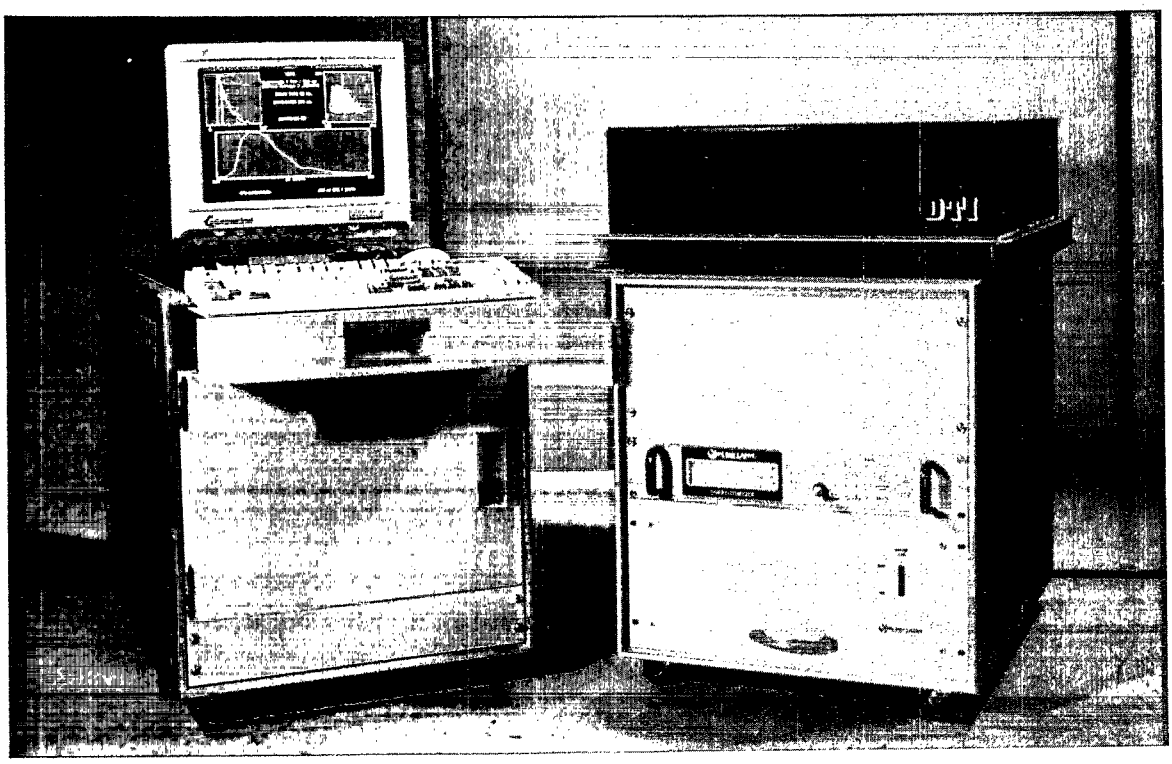
The Unisys Rapid Optical Screen Tool (ROST) is a tunable dye laser system for an optical cone penetrometer. The technology provides subsurface information including aromatic contaminants in soils.

The Unisys ROST components consist of a cone penetrometer (CPT), laser induced fluorescence (LIF) sensor, ROST system, detection system, and control computer. A complete ROST system consists of a truck, hydraulic rams and associated controllers, and the CPT itself. The weight of the truck provides a static reaction force, typically 20 tons, to advance the CPT. The CPT, which is mounted on the end of the series of push rods, contains sensors that continuously log tip stress and sleeve friction. The data from these sensors is used to map subsurface stratigraphy. Conductivity or pore pressure sensors can be driven into the ground simultaneously.

The LIF sensor can be deployed with any conventional CPT system and advanced along with other types of sensors. The LIF sensor contains a sapphire window that is mounted flush with the outside of the stainless steel LIF sensor. The sapphire window is mounted above the cone penetrometer tip. Light from an excitation laser passes through the sapphire window and is directed onto the soil through which the cone penetrometer is pushed. The aromatic contaminants in the soil are fluoresced, and fiber optics return this information to the surface.

The main ROST system components are:

- Neodymium-doped Yttrium Aluminum Garnet (Nd:YAG) primary laser



Rapid Optical Screen Tool

The SITE Program assesses but does not approve or endorse technologies.

- Tunable dye laser pumped by the Nd:YAG laser
- Fiber optic cable
- Monochromator to resolve the return fluorescence as a function of wavelength
- Photomultiplier tube (PMT) to convert photons into electrical signals
- Digital storage oscilloscope to capture waveforms from the PMT
- Control/analysis computer and software

The ROST system can be operated in both dynamic (push) and static modes. In the dynamic mode, the cone penetrometer equipped with the LIF sensor is advanced into the soil. In this mode, which Unisys refers to as fluorescence versus depth, the excitation laser wavelength and fluorescence emission monitoring wavelength are held constant. The fluorescence emission intensity is plotted as a function of depth below ground surface. The wave-length range has been selected because naphthalene, a principal polynuclear aromatic hydrocarbons (PAH) constituent of coal tar, fluoresces strongly under these conditions. The emission monochromator will be set at a wave-length determined during the laboratory analysis of the pre-demonstration samples and verified in the field.

Once areas of significant contamination have been identified in the dynamic mode, the ROST system can be operated in the static mode to identify fuel types. In this mode, the CPT is held at a fixed depth. The fluorescence technician, who is observing the fluorescence signal visually, can simply signal the hydraulic operator to halt the push. The ROST system also can operate in the static mode when additional push rods are added to the string.

Three people are needed to operate the Unisys ROST. Currently, the technology is marketed as a service, and is not for sale.

WASTE APPLICABILITY:

The Unisys ROST was designed to qualitatively and quantitatively identify classes of petroleum, PAH, and volatile organic compound contamination in subsurface soil samples.

STATUS:

The technology demonstration occurred in EPA Region 7, at sites in Iowa, Kansas, and Nebraska. The sampling and field analysis was conducted during September 1994.

After completing the demonstration, a Technology Evaluation Report (TER) will be prepared. The TER will objectively present the results of the demonstration and provide supporting documentation. In addition, an Innovative Technology Evaluation Report (ITER) will be prepared and published that summarizes the findings presented in the TER. These reports will help data users and technology reviewers assess the performance of each technology for possible use on future site characterization or remediation projects at hazardous waste sites.

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The SITE Program assesses but does not approve or endorse technologies.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
(Field Analytical Screening Program PCB Method)

TECHNOLOGY DESCRIPTION:

The field analytical screening program (FASP) polychlorinated biphenyl (PCB) method uses a temperature-programmable gas chromatograph (GC) equipped with an electron capture detector (ECD) to identify and quantify PCBs. Gas chromatography is an EPA-approved method for determining PCB concentrations. The FASP PCB method is a modified version of EPA SW-846 Method 8000.

To perform the FASP PCB method on soil samples, PCBs are extracted from the samples, injected into a GC, and identified and quantified with an ECD. Chromatograms produced by this equipment for each sample are compared to the chromatograms of PCB standards. Peak patterns and retention times from the chromatograms are used to identify and quantify PCBs in the soil sample extract. In addition to the GC, the operator may use an autosampler that automatically injects equal amounts of the sample extract into the GC column. The autosampler ensures that the correct amount of extract is used for each analysis and allows continual analysis without an operator.

The FASP PCB method has both advantages and limitations when used under field conditions. The method can 1) quickly provide results, 2) provide results that are comparable to formal laboratories in terms of statistical accuracy, 3) identify individual Aroclors, and 4) provide results with detection limits comparable to those of formal laboratories.

Instrumentation and equipment required for the FASP PCB method are not highly portable. When mounted in a mobile laboratory trailer, however, the method can operate on or near most sites relatively easily. Use of this method requires electricity, and Aroclor standards require refrigeration. An exhaust hood and carrier gases also are needed. A trained and experienced operator is needed for the method to produce reliable results. The operator should have at least 6 months of GC experience and 1 month of PCB analysis experience.

Soil samples must be extracted before analysis begins. Hexane and sulfuric acid are used during the extraction process, which removes potential interferences from the soil sample.

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The FASP PCB method can identify and quantify PCBs in soil and water samples.

STATUS:

The FASP PCB method was demonstrated under the SITE Program at a well-characterized, PCB-contaminated site. During the demonstration, 112 soil samples, 32 field duplicates, and 2 performance evaluation samples were analyzed with the FASP PCB method. A confirmatory laboratory analyzed the samples using SW-846 Method 8080. The accuracy and precision of the FASP PCB method was evaluated by directly comparing its data with the data from the confirmatory laboratory. In addition, the operational characteristics and performance factors of the FASP PCB method were evaluated.

The results from this SITE demonstration are included in a Technology Evaluation Report that is undergoing peer review and will be published in 1994.

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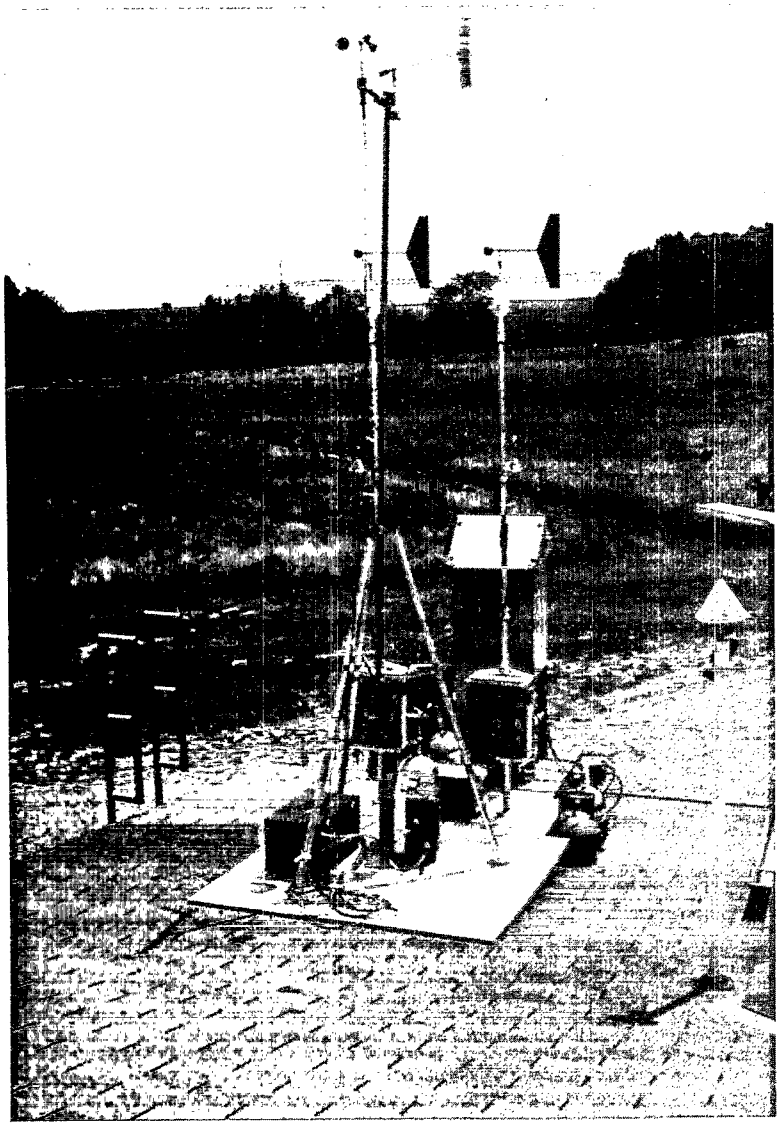
The SITE Program assesses but does not approve or endorse technologies.

XONTECH INCORPORATED
(XonTech Sector Sampler)

TECHNOLOGY DESCRIPTION:

The XonTech sector sampler collects time-integrated whole air samples in Summa™-polished canisters (see figure below). The territory surrounding the sampler is divided into two sectors: an "in" sector, which lies in the general direction of a suspected pollutant-emitting "target" and the "out" sector, which encompasses all territory not part of the "in" sector. When wind velocity exceeds 0.37 meter per second (m/s) from the direction of the target, the first canister is filled. When the wind velocity exceeds 0.37 m/s from any other direction, the



Sector Sampler

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other canister is filled. When the wind velocity falls below 0.37 m/s either canister or neither canister may receive the sample. Over an extended period of time, a target sample and a background sample are collected.

WASTE APPLICABILITY:

The XonTech sector sampler can monitor volatile organic compound emissions from hazardous waste sites and other emission sources before and during remediation. Short-term sampling can determine which high concentration compounds are emitted from a site. Long-term monitoring can assess an emission source's effects on the local population.

STATUS:

The sector sampler's usefulness has been demonstrated in two short-term field studies. Mathematical methods for processing data have been developed and shown to be appropriate. Remaining issues include 1) wind field consistency between source and receptor site, 2) treatment of data taken during stagnant conditions, and 3) applicability to a wider variety of compounds, including polar and odorous compounds.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Joachim Pleil
U.S. EPA
Atmospheric Research and Exposure
Assessment Laboratory
MD-44
Research Triangle Park, NC 27711
919-541-4680
Fax: 919-541-0239

TECHNOLOGY DEVELOPER CONTACT:
Matt Young
XonTech Incorporated
6862 Hayvenhurst Avenue
Van Nuys, CA 91406
818-787-7380
Fax: 818-787-8132

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INFORMATION REQUEST FORM

The EPA's Risk Reduction Engineering Laboratory is responsible for testing and evaluating technologies used at Superfund site cleanups. To receive publications about these activities, indicate your area of interest by checking the appropriate box(es) below and mail the top half of this sheet to the following address:

U.S. Environmental Protection Agency
Center for Environmental Research Information
26 West Martin Luther King Drive
Cincinnati, Ohio 45268
Attention: ORD Publications Unit (MS-G72)

(A9) ☐ Superfund
(A8) ☐ Superfund Innovative Technology Evaluation (SITE) Program

Name _____
Firm _____
Address _____
City, State, Zip Code _____

REQUEST FOR PROPOSAL FORM

EPA plans to issue two requests for proposals (RFP) during the coming year; one in January 1995 for the Demonstration Program (SITE 010), and the other in July 1995 for the Emerging Technology Program (E09). To receive these RFPs, indicate your area of interest by checking the appropriate box(es) below and mail the bottom half of this sheet to the following address:

U.S. Environmental Protection Agency
Risk Reduction Engineering Laboratory
26 West Martin Luther King Drive
Cincinnati, Ohio 45268
Attention: RFPs (MS-215)

(009) ☐ Demonstration Program RFP
(E08) ☐ Emerging Technology Program RFP

Name _____
Firm _____
Address _____
City, State, Zip Code _____

Documents Available from the U.S. EPA Risk Reduction Engineering Laboratory Superfund Technology Demonstration Division[1]

General Publications

- ❑ SITE Program: Annual Report to Congress 1993 (EPA/540/R-94/518)
- ❑ SITE Profiles, Sixth Edition (EPA/540/R-93/526)
- ❑ Survey of Materials Handling Technologies Used at Hazardous Waste Sites (EPA/540/2-91/010)

Demonstration Project Results

Accutech Pneumatic Fracturing Extraction and Hot Gas Injection, Phase I

- ❑ Technology Evaluation (EPA/540/R-93/509) PB93-216596
- ❑ Technology Demo. Summary (EPA/540/SR-93/509)[3]
- ❑ Demonstration Bulletin (EPA/540/MR-93/509)[3]
- ❑ Applications Analysis (EPA/540/AR-93/509) PB94-117439

American Combustion—Oxygen Enhanced Incineration

- ❑ Technology Evaluation (EPA/540/5-89/008)
- ❑ Applications Analysis (EPA/540/A5-89/008)
- ❑ Technology Demo. Summary (EPA/540/S5-89/008)[3]
- ❑ Demonstration Bulletin (EPA/540/M5-89/008)[3]

Augmented In-Situ Subsurface Bioremediation Process, Bio-Rem, Inc.

- ❑ Demonstration Bulletin (EPA/540/MR-93/527)[3]

AWD Technologies, Inc.—Integrated Vapor Extraction and Steam Vacuum Stripping

- ❑ Applications Analysis (EPA/540/A5-91/002) PB92-218379
- ❑ Demonstration Bulletin (EPA/540/M5-91/002)[3]

Babcock and Wilcox—Cyclone Furnace Vitrification

- ❑ Technology Evaluation Vol. I (EPA/540/R-92/017A) PB92-222215
- ❑ Technology Evaluation Vol. II (EPA/540/R-92/017B) PB92-222223
- ❑ Applications Analysis (EPA/540/AR-92/017) PB93-122315
- ❑ Technology Demo. Summary (EPA/540/SR-92/017)[3]
- ❑ Demonstration Bulletin (EPA/540/MR-92/011)

Bergmann USA—Soil/Sediment Washing System

- ❑ Demonstration Bulletin (EPA/540/MR-92/075)

Bescorp Soil Washing System Battery Enterprises Site—Brice Environmental Services, Inc.

- ❑ Demonstration Bulletin (EPA/540/MR-93/503)

Biogenesis Soil Washing Technology

- ❑ Demonstration Bulletin (EPA/540/MR-93/510)
- ❑ Innovative Technology Evaluation Report (EPA/540/R-93/510)
- ❑ Site Technology Capsule (EPA/540/SR-93/510)[3]

Biotrol—Biotreatment of Groundwater

- ❑ Technology Evaluation (EPA/540/5-91/001) PB92-110048
- ❑ Applications Analysis (EPA/540/A5-91/001)
- ❑ Technology Demo. Summary (EPA/540/S5-91/001)
- ❑ Demonstration Bulletin (EPA/540/M5-91/001)

Biotrol—Soil Washing System

- ❑ Technology Evaluation Vol. I (EPA/540/5-91/003a) PB92-115310
- ❑ Technology Evaluation Vol. II Part A (EPA/540/5-91/003b) PB92-115328
- ❑ Technology Evaluation Vol. II Part B (EPA/540/5-91/003c) PB92-115336
- ❑ Applications Analysis (EPA/540/A5-91/003)
- ❑ Technology Demo. Summary (EPA/540/S5-91/003)
- ❑ Demonstration Bulletin (EPA/540/M5-91/003)

CF Systems Corp.—Solvent Extraction

- ❑ Technology Evaluation Vol. I (EPA/540/5-90/002)
- ❑ Technology Evaluation Vol. II (EPA/540/5-90/002a) PB90-186503
- ❑ Applications Analysis (EPA/540/A5-90/002)
- ❑ Technology Demo. Summary (EPA/540/S5-90/002)

Chemfix Technologies, Inc.—Chemical Fixation/Stabilization

- ❑ Technology Evaluation Vol. I (EPA/540/5-89/011a) PB91-127696
- ❑ Technology Evaluation Vol. II (EPA/540/5-89/011b) PB90-274127

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[1] Order documents free of charge by calling EPA's Center for Environmental Research Information (CERI) at 513-569-7562.

[2] Documents with a PB number are out of stock in CERI and must be ordered by that number at cost from
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5285 Port Royal Road
Springfield VA 22161
Telephone 703-487-4650.

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- ❑ Applications Analysis (EPA/540/A5-89/011)
- ❑ Technology Demo. Summary (EPA/540/S5-89/011)[3]
- ❑ Demonstration Bulletin (EPA/540/M5-89/011)[3]

Colloid Polishing Filter Method Filter Flow Technology, Inc.

- ❑ Demonstration Bulletin (EPA/540/MR-94/501)
- ❑ Capsule (EPA/540/R-94/501a)

Dehydro-Tech—Carver-Greenfield

- ❑ Technology Evaluation (EPA/540/R-92/002) PB92-217462
- ❑ Applications Analysis (EPA/540/AR-92/002)
- ❑ Technology Demo. Summary (EPA/540/SR-92/002)
- ❑ Demonstration Bulletin (EPA/540/MR-92/002)

Dupont/Oberlin—Microfiltration System

- ❑ Technology Evaluation (EPA/540/5-90/007) PB92-153410
- ❑ Applications Analysis (EPA/540/A5-90/007)
- ❑ Technology Demo. Summary (EPA/540/S5-90/007)
- ❑ Demonstration Bulletin (EPA/540/M5-90/007)

Ex-Situ Anaerobic Bioremediation System, Dinoseb, J.R. Simplot Company

- ❑ Demonstration Bulletin (EPA/540/MR-94/508)

Forager Sponge Technology

- ❑ Demonstration Bulletin (EPA/540/MR-94/522)

Fungal Treatment Technology

- ❑ Demonstration Bulletin (EPA/540/MR-93/514)

Gas-Phase Chemical Reduction EcoLogic International, Inc

- ❑ Demonstration Bulletin (EPA/540/MR-93/522)
- ❑ Technology Evaluation—Vol. I (EPA/540/R-93/522a)
- ❑ Technology Evaluation—Appendices (EPA/540/R-93/522b)

GIS/KEY Environmental Data Management System

- ❑ Innovative Technology Evaluation Report (EPA/540/R-94/505)
- ❑ SITE Technology Capsule (EPA/540/SR-94/505)
- ❑ Demonstration Bulletin (EPA/540/MR-94/505)

Hazcon—Solidification

- ❑ Technology Evaluation Vol. I (EPA/540/5-89/001a) PB89-158810
- ❑ Technology Evaluation Vol. II EPA/540/5-89/001b) PB89-158828
- ❑ Applications Analysis (EPA/540/A5-89/001)
- ❑ Technology Demo. Summary (EPA/540/S5-89/001)[3]
- ❑ Demonstration Bulletin (EPA/540/M5-89/001)[3]

Horsehead Resource Development

- ❑ Technology Evaluation Vol I (EPA/540/5-91/005) PB92-205855
- ❑ Applications Analysis (EPA/540/A5-91/005)
- ❑ Technology Demo. Summary (EPA/540/S5-91/005)
- ❑ Demonstration Bulletin (EPA/540/M5-91/005)

Hrubetz Environmental Services, Site Demonstration Program

- ❑ Demonstration Bulletin (EPA/540/MR-93/524)

Hydraulic Fracturing of Contaminated Soil

- ❑ Demonstration Bulletin (EPA/540/MR-93/505)
- ❑ Technology Evaluation and Applications Analysis Combined (EPA/540/R-93/505)
- ❑ Technology Demo. Summary (EPA/540/SR-93/505)

In-Situ Steam Enhanced Recovery System—Hughes Environmental Systems, Inc.

- ❑ Demonstration Bulletin (EPA/540/MR-94/510)

In-Situ Vitrification—Geosafe Corporation

- ❑ Demonstration Bulletin (EPA/540/MR-94/520)

IWT/GeoCon In-Situ Stabilization

- ❑ Technology Evaluation Vol. I (EPA/540/5-89/004a)
- ❑ Technology Evaluation Vol. II (EPA/540/5-89/004b) PB89-194179
- ❑ Technology Evaluation Vol. III (EPA/540/5-89/004c) PB90-269069
- ❑ Technology Evaluation Vol. IV (EPA/540/5-89/004d) PB90-269077
- ❑ Applications Analysis (EPA/540/A5-89/004)
- ❑ Technology Demo. Summary (EPA/540/S5-89/004)
- ❑ Technology Demo. Summary., Update Report (EPA/540/S5-89/004a)
- ❑ Demonstration Bulletin (EPA/540/M5-89/004)[3]

Low Temperature Thermal Aeration (LTTA) System, Canonie Environmental Services, Inc.

- ❑ Demonstration Bulletin (EPA/540/MR-93/504)

Magnum Water Technology—CAV-OX Ultraviolet Oxidation Process

- ❑ Demonstration Bulletin (EPA/540/MR-93/520)
- ❑ Applications Analysis (EPA/540/AR-93/520)

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Demonstration Project Results (continued)

McColl Superfund Site—Demonstration of a Trial Excavation
- ❑ Technology Evaluation (EPA/540/R-92/015) PB92-226448
- ❑ Applications Analysis (EPA/540/AR-92/015)
- ❑ Technology Demo. Summary (EPA/540/SR-92/015)

Microfiltration Technology EPOC Water, Inc.
- ❑ Demonstration Bulletin (EPA/540/MR-93/513)

Mobile Volume Reduction Unit at the Sand Creek Superfund Site
- ❑ Treatability Study Bulletin (EPA/540/MR-93/512)

Mobile Volume Reduction Unit at the Escambia Superfund Site
- ❑ Treatability Study Bulletin (EPA/540/MR-93/511)

Ogden Circulating Bed Combustor—McColl Superfund Site
- ❑ Technology Evaluation (EPA/540/R-92/001)
- ❑ Demonstration Bulletin (EPA/540/MR-92/001)

Outboard Marine Corporation Site—Soiltech Anaerobic Thermal Processor
- ❑ Demonstration Bulletin (EPA/540/MR-92/078)

Perox-Pure™ Chemical Oxidation Treatment
- ❑ Demonstration Bulletin (EPA/540/MR-93/501)
- ❑ Applications Analysis (EPA/540/AR-93/501)
- ❑ Technology Evaluation (EPA/540/R-93/501) PB93-213528
- ❑ Technology Demo. Summary (EPA/540/SR-93/501)

Pilot-Scale Demonstration of Slurry-Phase Biological Reactor for Creosote-Contaminated Wastewater
- ❑ Technology Demo. Summary (EPA/540/S5-91/009)
- ❑ Technology Evaluation Vol. I (EPA/540/5-91/009) PB93-205532
- ❑ Applications Analysis (EPA/540/A5-91/009)
- ❑ Demonstration Bulletin (EPA/540/M5-91/009)

PO*WW*ER™ Wastewater Treatment System Lake Charles Treatment Center
- ❑ Applications Analysis (EPA/540/AR-93/506)
- ❑ Demonstration Bulletin (EPA/540/MR-93/506)
- ❑ Technology Evaluation Vol. I (EPA/540/R-93/506A) PB94-160637
- ❑ Technology Evaluation Vol. II (EPA/540/R-93/506B) PB94-160660
- ❑ Technology Demo. Summary (EPA/540/SR-93/506)

Resources Conservation Company—The Basic Extractive Sludge Treatment (B.E.S.T.)
- ❑ Demonstration Bulletin (EPA/540/MR-92/079)
- ❑ Applications Analysis (EPA/540/AR-92/079)
- ❑ Technology Evaluation Vol. I (EPA/540/R-92/079a) PB93-227122
- ❑ Technology Evaluation Vol. II, Part 1 (EPA/540/R-92/079b) PB93-227130
- ❑ Technology Evaluation Vol. II, Part 2 (EPA/540/R-92/079c) PB93-227148
- ❑ Technology Evaluation Vol. II, Part 3 (EPA/540/R-92/079d) PB93-227155
- ❑ Technology Demo. Summary (EPA/540/SR-92/079)

Retech Plasma Centrifugal Furnace
- ❑ Technology Evaluation Vol. I (EPA/540/5-91/007a) PB 92-216035
- ❑ Technology Evaluation Vol. II (EPA/540/5-91/007b) PB92-216043
- ❑ Applications Analysis (EPA/540/A5-91/007) PB92-218791
- ❑ Technology Demo. Summary (EPA/540/S5-91/007)
- ❑ Demonstration Bulletin (EPA/540/M5-91/007)

Roy F. Weston, Inc.—Low Temperature Thermal Treatment (LT3) System
- ❑ Demonstration Bulletin (EPA/540/MR-92/019)
- ❑ Applications Analysis (EPA/540/AR-92/019)

SBP Technologies—Membrane Filtration
- ❑ Demonstration Bulletin (EPA/540/MR-92/014)
- ❑ Applications Analysis (EPA/540/AR-92/014)

Shirco—Infrared Incineration
- ❑ Technology Evaluation—Peake Oil (EPA/540/5-88/002a)
- ❑ Technology Evaluation—Rose Township (EPA/540/5-89/007a)
- ❑ Technology Evaluation—Rose Township Vol. II (EPA/540/5-89/007b), PB89-167910
- ❑ Applications Analysis (EPA/540/A5-89/010)
- ❑ Technology Demo. Summary (EPA/540/S5-89/007)[3]
- ❑ Demonstration Bulletin (EPA/540/M5-88/002)[3]
- ❑ Technology Evaluation Report—Peake Oil Vol. II (EPA/540/5-88/002B) PB89-116024

Silicate Technology Corporation—Solidification/Stabilization of Organic/Inorganic Contaminants
- ❑ Demonstration Bulletin (EPA/540/MR-92/010)
- ❑ Applications Analysis (EPA/540/AR-92/010) PB93-172948

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Demonstration Project Results (continued)

Soiltech ATP Systems—Aostra-Soil-Tech Anaerobic Thermal Process

- ❑ Demonstration Bulletin (EPA/540/MR-92/008)

Solditech, Inc.—Solidification

- ❑ Technology Evaluation Vol. I (EPA/540/5-89/005a)
- ❑ Technology Evaluation Vol. II (EPA/540/5-89/005b) PB90-191768
- ❑ Applications Analysis (EPA/540/A5-89/005)
- ❑ Technology Demo. Summary (EPA/540/S5-89/005)[3]
- ❑ Demonstration Bulletin (EPA/540/M5-89/005)

Terra Kleen Solvent Extraction Technology—Terra Kleen Response Group, Inc.

- ❑ Demonstration Bulletin (EPA/540/MR-94/521)

Terra Vac—Vacuum Extraction

- ❑ Technology Evaluation Vol. I (EPA/540/5-89/003a) PB89-192025
- ❑ Technology Evaluation Vol. II (EPA/540/5-89/003b) PB89-192033
- ❑ Applications Analysis (EPA/540/A5-89/003)
- ❑ Technology Demo. Summary (EPA/540/S5-89/003)
- ❑ Demonstration Bulletin (EPA/540/M5-89/003)[3]

Texaco Gasification Process—Texaco, Inc.

- ❑ Demonstration Bulletin (EPA/540/MR-94/514)

Thermal Desorption System, Clean Berkshires, Inc.

- ❑ Demonstration Bulletin (EPA/540/MR-94/507)
- ❑ Capsule (EPA/540/R-94/507a)[3]

Thermal Desorption Unit Eco Logic International, Inc.

- ❑ Demonstration Bulletin (EPA/540/MR-94/504)

Thorneco, Inc.—Enzyme-Activated Cellulose Technology

- ❑ Treatability Study Bulletin (EPA/540/MR-92/018)[3]

Toronto Harbour Commissioners—Soil Recycling Treatment Train

- ❑ Demonstration Bulletin (EPA/540/MR-92/015)
- ❑ Applications Analysis (EPA/540/AR-93/517)
- ❑ Technology Evaluation (EPA/540/R-93/517) PB93-216067
- ❑ Technology Demo. Summary (EPA/540/SR-93/517)

Toxic Treatments (USA)—In-Situ Steam/Hot Air Stripping

- ❑ Applications Analysis (EPA/540/A5-90/008)
- ❑ Demonstration Bulletin (EPA/540/M5-90/003)

Ultrox International—UV Ozone Treatment for Liquids

- ❑ Technology Evaluation (EPA/540/5-89/012) PB90-198177
- ❑ Applications Analysis (EPA/540/A5-89/012)
- ❑ Technology Demo. Summary (EPA/540/S5-89/012)
- ❑ Demonstration Bulletin (EPA/540/M5-89/012)

U.S. EPA—Design and Development of a Pilot-Scale Debris Decontamination System

- ❑ Technical Evaluation (EPA/540/5-91/006a)
- ❑ Technical Evaluation Vol. II (EPA/540/5-91/006b) PB91-231464
- ❑ Technology Demo. Summary (EPA/540/S5-91/006)

U.S. EPA—Mobile Volume Reduction Unit

- ❑ Demonstration Bulletin (EPA/540/MR-93/508)
- ❑ Applications Analysis (EPA/540/AR-93/508)
- ❑ Technology Evaluation (EPA/540/R-93/508) PB94-136264
- ❑ Technology Demo. Summary (EPA/540/SR-93/508)

X-TRAX Model 100 Thermal Desorption System Chemical Waste Management

- ❑ Demonstration Bulletin (EPA/540/MR-93/502)

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Emerging Technologies Program Reports

Acid Extraction Treatment System for Treatment of Metal-Contaminated Soils

- ❑ Emerging Tech. Report (EPA/540/R-94/513)

Aluminum Company of America—Bioscrubber for Removing Hazardous Organic Emission from Soil, Water, and Air Decontamination Process

- ❑ Emerging Tech. Report (EPA/540/R-93/521) PB93-227205
- ❑ Emerging Tech. Bulletin (EPA/540/F-93/507)
- ❑ Emerging Tech. Summary (EPA/540/SR-93/521)
- ❑ Journal Article AWMA Vol. 44, No. 3, March 1994

Atomic Energy of Canada Limited—Chemical Treatment and Ultrafiltration

- ❑ Emerging Tech. Bulletin (EPA/540/F-92/002)

Babcock and Wilcox—Cyclone Furnace Soil Vitrification

- ❑ Emerging Tech. Bulletin (EPA/540/F-92/010)
- ❑ Emerging Tech. Report (EPA/540/R-93/507) PB93-163038
- ❑ Emerging Tech. Summary (EPA/540/SR-93/507)

Battelle Memorial Institute—Development of Electro-Acoustic Soil Decontamination (ESD) Process for In Situ Applications

- ❑ Emerging Technology (EPA/540/5-90/004) PB90-204728
- ❑ Emerging Tech. Summary (EPA/540/S5-90/004)[3]

Bio-Recovery Systems—Removal and Recovery of Metal Ions from Groundwater

- ❑ Emerging Technology (EPA/540/5-90/005a)
- ❑ Emerging Tech.—Appendices (EPA/540/5-90/005b) PB90-252602
- ❑ Emerging Tech. Summary (EPA/540/S5-90/005)
- ❑ Emerging Tech. Bulletin (EPA/540/F-92/003)
- ❑ Journal Article AWMA Vol. 41, No. 10, October 91

Biotrol, Inc.—Methanotrophic Bioreactor System

- ❑ Emerging Tech. Bulletin (EPA/540/F-93/506)
- ❑ Emerging Tech. Summary (EPA/540/SR-93/505)
- ❑ Journal Article AWMA Vol. 43, No. 11, November 1993

Center for Hazardous Materials Research—Acid Extraction Treatment System for Treatment of Metal Contaminated Soils

- ❑ Emerging Tech. Report (EPA/540/R-94/513)
- ❑ Emerging Tech. Summary (EPA/540/SR-94/513)

Colorado School of Mines—Constructed Wetlands Receiving Acid Mine Drainage

- ❑ Emerging Tech. Summary (EPA/540/SR-92/523)
- ❑ Emerging Tech. Report (EPA/540/R-93/523) PB93-233914
- ❑ Emerging Tech. Bulletin (EPA/540/F-92/001)

Colorado School of Mines—Constructed Wetlands Treatment for Toxic Metal Contaminated Waters

- ❑ Emerging Tech. Bulletin (EPA/540/F-92/001)

Electro-Pure Systems—Alternating Current Electrocoagulation

- ❑ Emerging Tech. Bulletin (EPA/540/F-92/011)
- ❑ Emerging Tech. Summary (EPA/540/S-93/504)
- ❑ Journal Article AWMA Vol. 43, No. 5, May 1993

Energy and Environmental Engineering—Laser-Induced Photochemical Oxidative Destruction

- ❑ Emerging Tech. Bulletin (EPA/540/F-92/004)
- ❑ Emerging Tech. Report (EPA/540/R-92/080) PB93-131431
- ❑ Emerging Tech. Summary (EPA/540/SR-92/080)

Energy and Environmental Research Corporation

- ❑ Emerging Tech. Bulletin (EPA/540/F-93/508)

Florida International University

— ***Electron Beam Treatment for Removal of Benzene and Toluene from Aqueous Streams and Sludge***

- ❑ Emerging Tech. Bulletin (EPA/540/F-93/502)

— ***Electron Beam Treatment for the Trichloroethylene and Tetrachloroethylene from Aqueous Stream***

- ❑ Emerging Tech. Bulletin (EPA/540/F-92/009)

— ***Removal of Phenol from Aqueous Solutions Using High Energy Electron Beam Irradiation***

- ❑ Emerging Tech. Bulletin (EPA/540/F-93/509)

Ghea Associates Process

- ❑ Emerging Tech. Bulletin (EPA/540/F-94/509)

Institute of Gas Technology (CBT-Chemical and Biological Treatment)

- ❑ Emerging Tech. Bulletin (EPA/540/F-94/504)

Institute of Gas Technology—Biological Degradation Process

- ❑ Emerging Tech. Bulletin (EPA/540/F-94/501)

IT Corporation—Photolysis/Biodegradation of PCB and PCDD/PCDF Contaminated Soils

- ❑ Emerging Tech. Bulletin (EPA/540/F-94/502)

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Emerging Technologies Program Reports (continued)

J.R. Simplot—Anaerobic Destruction of Nitroaromatics
- ❑ Journal Article App. Env. Micro, Vol. 58, pp. 1683-89

Matrix Photocatalytic—Tio_2 UV Oxidation
- ❑ Journal Articles (EPA/540/A-93/282, EPA/540/J-93/297).

Membrane Technology and Research, Inc.—Volatile Organic Compound Removal from Air Streams by Membrane Separation
- ❑ Emerging Tech. Bulletin (EPA/540/F-94/503)

M.L. Energia, Inc.—Reductive Photo-Dechlorination Process for Safe Conversion of Hazardous Chlorocarbon Waste Streams
- ❑ Emerging Tech. Bulletin (EPA/540/F-94/509)

New Jersey Institute of Technology—Reversible Adsorption on Surface-Active Componds
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PURUS, Inc.—Destruction of Organic Contaminants in Air Using Advanced Ultraviolet Flashlamps
- ❑ Emerging Tech. Bulletin (EPA/540/F-93/501)
- ❑ Emerging Tech. Summary (EPA/540/SR-93/516)
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- ❑ Emerging Tech. Brochure (EPA/540/F-94/505)

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University of Washington—Metals Treatment at Superfund Sites by Adsorptive Filtration
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- ❑ Emerging Tech. Report (EPA/540/R-93/515) PB93-231165
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Wastewater Technology Centre—A Cross-Flow Pervaporation System for Removal of VOCs from Contaminated Soil
- ❑ Emerging Tech. Bulletin (EPA/540/F-93/503)
- ❑ Emerging Tech. Report (EPA/540/R-94/512) PB94-170230
- ❑ Emerging Tech. Summary (EPA/540/SR-94/512)

Volatile Organic Compound Removal from Air Streams by Membrane Separation
- ❑ Emerging Tech. Bulletin (EPA/540/F-94/503)

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(6 technology demonstrations)

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ECOVA (SHIRCO) Infrared Incineration System, Rose Twp., MI - 3/89

EMTECH (HAZCON) Solidification Process, Douglassville, PA - 10/87

IWT/GEO-CON In Situ Stabilization/Solidification, Hialeah, FL - 4/88

TERRA VAC Vacuum Extraction System, Groveland, MA - 1/88

CF SYSTEMS Solvent Extraction Unit, New Bedford, MA - 3/89

S2 SITE PROGRAM
(4 technology demonstrations):

ULTROX Ultraviolet Radiation and Oxidation, San Jose, CA - 3/89

BIOTROL Biological Aqueous Treatment, New Brighton, MN 9/89

BIOTROL Soil Washing System, New Brighton, MN 9/89

IT/RREL Debris Washing System, Hopkinsville, KY - 12/89

S3 SITE PROGRAM
(4 technology demonstrations):

SOLIDITECH Solidification and Stabilization, Morganville, NJ - 12/88

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S4 SITE PROGRAM
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E.I. DUPONT/OBERLIN FILER Membrane Microfiltration, Palmerton, PA - 5/90

HORSEHEAD Flame Reactor, Atlanta, GA - 3/91

RETECH Plasma Centrifugal Furnace, Butte, MT - 7/91

BABCOCK & WILCOX Cyclone Furnace, Alliance, OH - 11/91

S5 SITE PROGRAM
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STC Immobilization of Organic/Inorganic Contaminants in Soils, Selma, CA - 11/90

THC Soil Recycle Treatment Train at Toronto Harbor, Toronto, Ont., Canada - 5/92

R.C.C. Basic Extractive Sludge Treatment (B.E.S.T.), Grand Calumet River, Gary, IN - 7/92

Peroxidation Systems, Inc. Purox-Pure Chemical Oxidation Treatment, Altamont Hills, CA - 9/92

S6 SITE PROGRAM
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Bergmann Soil/Sediment Washing Technology, Saginaw Bay, MI - 2/93

BESCORP Soil Washing System, Fairbanks, AK - 8/92

ELI Eco Logic International Inc. Hydrogen Reduction Gas-Phase Chemical Reduction Process, Bay City, MI - 11/93

Magnum Water Technology CAV-OX Ultraviloet Oxidation Process, Edwards AFB, CA - 1/94

R1 RREL/RCB RESEARCH PROGRAMS

This composite videotape contains five documentaries on research projects conducted under the auspices of the Risk Reduction Engineering Laboratory's Releases Control Branch:

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Dioxin and the Mobile Incineration System

Mobile Carbon Regeneration System

Mobile Soils Washing System

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